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Evaluation and modeling of nonpoint source pollution using GIS techniques

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by

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INTRODUCTION

Agriculture has been identified as the largest contributor of nonpoint source pollution of surface and ground water systems in the United States. In a 1986 Report to Congress, the Environmental Protection Agency (EPA) noted that routine agricultural activities is responsible for over 60% of the surface water pollution problems nationwide(EPA, 1990). Accelerated erosion of productive land, nutrients (primarily, nitrogen and phosphorus) and pesticide loading from agricultural runoff, and pathogens from feedlots and urban runoff and sewage are the primary causes of surface water quality impairments.

In recent years, federal and state agencies charged with water quality protection have addressed the nonpoint source pollution problem by establishing some relationships between land management practices and environmental/water quality degradation. Efforts have been directed at mitigating adverse agricultural impacts by: (a) expanding the knowledge of the processes influencing surface hydrology and the fate of agrichemicals in the environment; (b) establishing methods and tools to evaluate the extent and nature of agricultural impacts on water quality; and (c) translating the accumulated information into improved land management practices that are both environmentally sound and sustainable.

Determining the amounts of pollutants from agricultural land can be achieved through long-term on-site monitoring and simulation modeling. However, the tormer is very labor intensive and expensive. Therefore, simulation modeling of nonpoint source pollution has been used quite frequently to provide guidelines in the development of land management strategies and as decision support tools.

In simulation modeling, mathematical relationships are used to describe the behavior of the physical system or to quantitatively represent the process occurring within the system. Two basic types of models have been widely used to evaluate nonpoint source pollution impacts on water quality. These include the lumped parameter models and distributed parameter models. In general, distributed models have greater accuracy in estimating spatially variable processes than the lumped model (Beasley et al., 1982).

Irrespective of its type, models are powerful tools for understanding the probable effects of changes in alternative land development and/or management strategies on water quality. They provide the tools for testing hypothesis and assessing effectiveness of land management scenarios before they are juxtaposed on the natural system. However, several limitations, such as the inability to manipulate the large amounts of input data, restrict the widespread use of simulation model. Fortunately, recent developments in geographic information systems (GIS) technology provide the tool to spatially generate, store, manipulate, and retrieve the disparate input data required for modeling, particularly distributed-parameter modeling. For example, the Agricultural Nonpoint Source Pollution (AGNPS) distributed-parameter model, a cell-based model requires large amounts of input parameters, some of which are spatial, now is widely used in water quality modeling. All the spatial distributed parameters in AGNPS can be obtained or derived from a GIS, and in turn, can be exported into the AGNPS model. Manual encoding of AGNPS model input data can be quite cumbersome and expensive in terms of labor demands. Organization of model input data within GIS eliminates the data input bottlenecks experienced by both modelers and model users. Moreover, with the use of GIS, spatially distributed parameters including vegetative cover which are cost-effectively obtained by remote sensing, can be integrated with GIS to generate spatial data for modeling. For example, land cover/land use which influences many hydrologic processes, such as infiltration, runoff and soil moisture can be obtained from remote sensors. These information can be then related to numeric values for AGNPS model which can include hydrologic curve number, Manning roughness coefficient, and surface condition constant (Jakubanskas et al., 1992).

The purpose of this study is to integrate the AGNPS hydrologic/water quality model and ARC/INFO GIS for evaluation of nonpoint source pollution from agricultural activities. A computer program which provides the capabilities of file conversion between AGNPS and ARC/INFO and parameter derivation was developed to serve as an interface. The structure and function of the interface are introduced and an example application is used to examine the utility, efficiency and capability of the computer interface.

AGRICULTURAL NONPOINT SOURCE POLLUTION

Background

Water quality degradation from point and nonpoint sources is an important environmental issue in the United States. Points sources, such as discharges from industrial, sewage treatment systems, and feedlot surfaces, or leachate from landfills enter the environment at discrete locations and may be easily identified and controlled. Nonpoint sources, on the other hand, is diffuse and can be carried over and through runoff and percolation. These sources of pollution are much more difficult to identify and control. Since the water pollution from point sources can be detected and sufficient control could be achieved by managing the point source, attention has, over the past several years, shifted to pollution problems from nonpoint sources including agriculture.

Nonpoint source pollutants may partially deposit on land surface before they reach the receiving water. Consequently, nonpoint source are considered to be responsible for most of the water pollution problems. The major causes of nonpoint source pollution may come from: agriculture, mining, urban runoff, silviculture, and construction. Today, approximately 65% of nonpoint source is from agricultural sources. In a 1984 survey of Association of State and Interstate Water Pollution Control Administrators (ASIWPCA), 43% of the responding states indicated that the current nonpoint source problems are greater in magnitude than point-source problems, while 35% indicated that point and nonpoint problems are of equal importance in terms of impact (Savage, 1985).

Identification of Nonpoint Source Pollution Problems

Nonpoint sources play a major role in contributing to many of the water quality problems facing the nation. To identify the pollution problem area within an agricultural watershed, the contributed area should be defined first. Then, a control strategy can be designed to mitigate and/or alleviate the pollution problem. As with most types of nonpoint source pollution, agricultural nonpoint source pollution relates directly to the way in which the land is managed. There are several different sources associated with different impacts on the contributed area. These include: irrigated cropland; and nonirrigated cropland; animal production on rangeland and pasture; and concentrated livestock production.

The primary pollutants from irrigated and nonirrigated cropland are sediment, nutrients, and pesticides. Runoff from feedlots and barnyards deliver nutrients, organic matter, microorganisms, and other pollutants to receiving waters. Animal grazing also causes soil compaction and damage, thus increasing the soil erosion, sedimentation, and other related pollution problems through runoff. Livestock wastes from concentrated production facilities also contribute to significant water pollution problems (EPA, 1984).

Sediment is the most pervasive surface water contaminant from cropland. The potential for on farm delivery of sediment to receiving water depends on several factors, including sites characteristics, land slope, climate, and proximity to receiving water. Pollution generated on cropland also relates to crop type, tillage, and surface land management practices (e.g. tillage). On the impacts of water quality, sediment affects water temperature, turbidity and aquatic habits. Chemicals attached to the sediment, such as pesticides and nutrients, can also cause the water quality problems. Increase the amounts of pesticide application on cropland can accelerate the eutrophication of water body and the contamination of surface water and groundwater.

Rangeland and pasture can contribute significant amounts of sediment and nutrients to surface water if there is overgrazing. Erosion rates on pasture are usually slightly lower than on rangeland. Animal production on both rangeland and pasture also results in runoff of animal wastes. Each year, livestock on farms and ranches produce nearly 2 billion tons of liquid manure which contains approximately 7.7 million tons of nitrogen, 1.9 million tons of phosphorus, and 351 million tons of potassium. The pollution problems from animal production sources are pervasive on agricultural areas and widely dispersed nationally (Myers et al., 1985). With all of the above documented water quality problems, it is not at all surprising that intense effort has been focused on mitigating their impacts.

WATER QUALITY MODELING

Modeling Concept

A model is an approximate representation of the actual system. It can be divided into several subsystems or components. For example, the hydrologic cycle can be partitioned into different components, such as precipitation, evapotrans~~portation~~iration, infiltration, groundwater flow, and surface runoff. These components can be treated separately and/or represented in different theoretical/empirical relationships. The resulting model, therefore, depends upon the interactions among these individual components that represent the overall biophysical processes occurring within the system.

Since the early 1960s, mathematical models have been used extensively to analyze nonpoint source pollution of soil and water resources. These models have become useful and best available technology for analyzing and planning natural resource management systems. They provide greater benefits for water resource decision-making and also help to: (a) structure and direct field scale data collection, (b) analyze site-specific responses, (c) determine the accuracy to be used in evaluating input variables and parameters, (d) study the significance of spatial and temporal variability of landforms and processes, and (e) determine the observations needed to achieve a given degree of accuracy (Decoursey, 1985). In hydrologic/water quality modeling, several forms of model representation have been proposed. The following section describes, briefly, these forms of modeling philosophy.

Hydrologic Modeling

Incorporating randomness and spatial variability into the list of potential processes, hydrologic models can be grouped into: deterministic model; and stochastic model. In deterministic modeling, a general function describes the change in state processes at a given point in the landscape with no allowance for randomness in the processes. On the other hand, stochastic models incorporate random characteristics and predict potential likelihoods of state variables (eg, concentration of water quality parameters). Deterministic models can be further divided into lumped and distributed models (Figure 1). In lumped models, the system is spatially averaged over a large domain having heterogeneous properties. The model then aggregates all influences of spatial non-uniformities into equivalent point values, and evaluates the impact of spatially variable parameters by calculating effective homogeneous values for an entire area. In contrast, spatially variable hydrologic processes in distributed models are considered taking place at various points in the landscape. The model then attempts to incorporate spatially distributed data using algorithms that represent interactions between locations and state variables. In modeling landscape processes, distributed models provide a more accurate representation and estimation than lumped models (Beasley et al., 1982).

Types of Models

Hydrologic models can also be subdivided into field-scale and watershed-scale models on the basis of whether parameters are lumped or distributed at the landscape

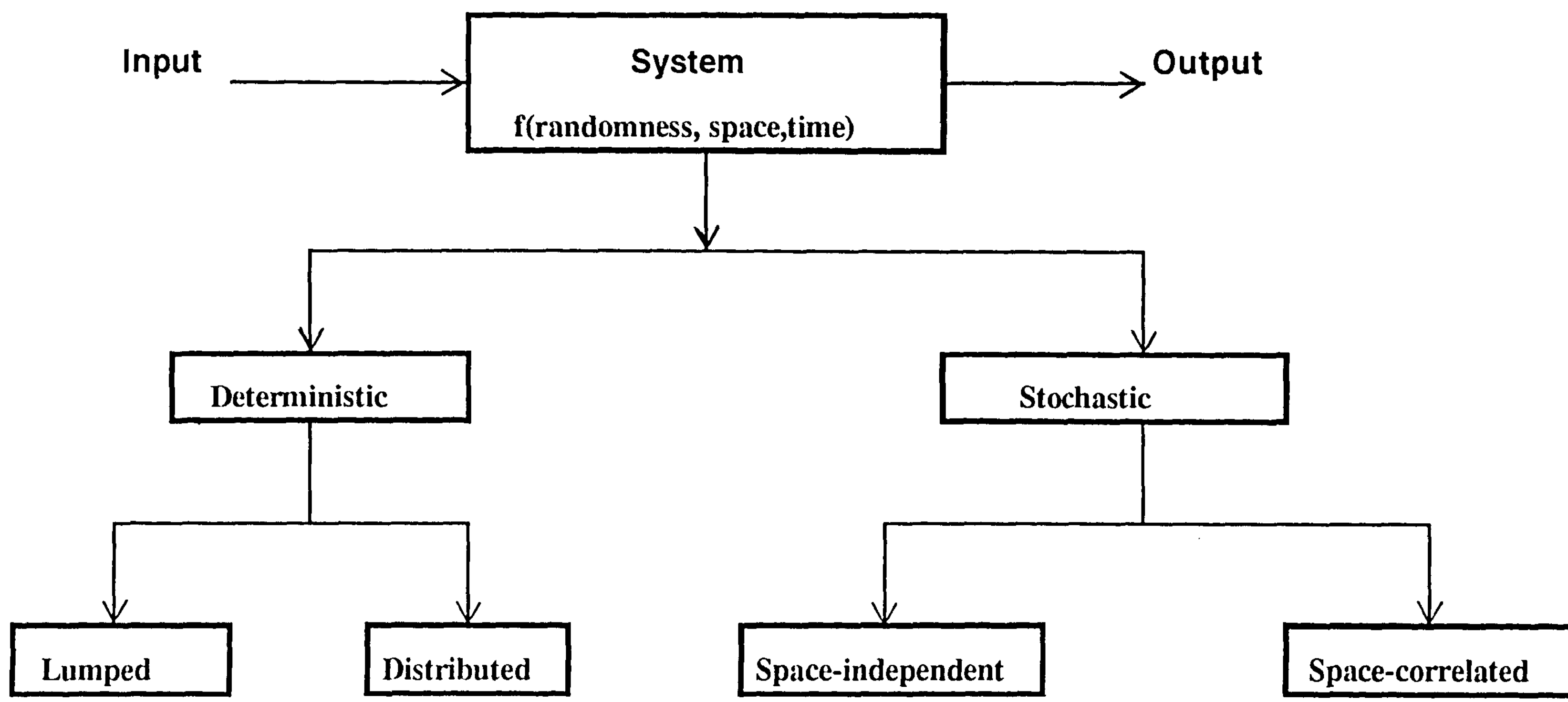


Figure 1. Classification of hydrologic models (Chow et al., 1988)

level. In field-scale modeling, the hydrologic process are described within a single field or land resource unit having uniform soils, weather, and topography. Typical examples of field-scale models used for evaluating surface hydrology and nonpoint source pollution include: CREAMS (Knisel, 1980), GLEAMS (Leonard et al., 1987), and PRZM (Carsel et al., 1984).

Watershed-scale models simulate hydrology and water quality related processes based on spatially distributed landscape characteristics. Routing algorithms are used to integrate cumulative effects at the watershed- or catchment-level. Some of the existing watershed-scale models are storm-event based, while others provide continuous simulation of processes and mechanisms over long periods of time. Typical examples of watershed-scale models include: AGNPS (Young et al., 1989), ANSWERS (Beasley and Huggin, 1982), and WEPP (Laflen et al., 1991). A summary of the characteristics in some of these models are shown in Table 1. Specific details of some lumped and distributed models are discussed the following sections.

CREAMS

Chemical Runoff and Erosion from Agricultural Management Systems (CREAMS) model is a field-scale model designed for predicting the impact of agricultural management systems on surface runoff, soil erosion, and water quality (Knisel, 1980). The model has three major components that represent: (1) hydrology, (2) soil erosion and sedimentation, and (3) chemical transport. The hydrology submodel estimates runoff volume, peak runoff, infiltration, evapotranspiration, soil moisture, and percolation.

Table 1. Summary of the characteristics of some simulation models (Heatwole et al., 1991)

Model	Time Scale	Watershed Characterization	Groundwater Loading	Parameters Simulated [a]
Field-scale				
CREAMS	continuous	aggregate	yes	S,N,P
GLEAMS	continuous	aggregate	yes	S,N,P
PRZM	continuous	aggregate	yes	S,P
WEPP	continuous	aggregate	yes	S
Watershed-scale				
AGNPS	event	distributed	no	S,N,COD
ANSWERS	event	distributed	no	S,N
WEPP(Grid)	continuous	distributed	no	S

[a] S = sediment, N = nutrient, P = pesticide, COD = chemical oxygen demand

The erosion/sedimentation submodel estimates sediment yield and particle size distribution of eroded sediment. The chemistry submodel estimates losses of dissolved and soil-attached nitrogen, phosphorus, and pesticides in surface runoff percolation and in eroded sediment (Knisel 1980).

GLEAMS

Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) is a microcomputer-based model developed to simulate the movement of water and chemicals (pesticide and nitrogen) within the crop root zone (Leonard et al., 1987). The model is an extension of the CREAMS model, and is continuous at a temporal scale (daily time step) although lumped at the landscape level. GLEAMS can simulate subsurface movement of pesticides and their metabolites within the plant root zone, and the vadoze zone (soil layer between the bottom of the plant rooting depth and the top of the water table).

PRZM

Pesticide Root Zone Model or PRZM (Carsel et al., 1984), developed by the U.S. Environmental Protection Agency, is a field-scale hydrology and pesticide transport model designed to provide continuous simulation of the effects of agricultural management practices on pesticide fate and transport. The model can simulate the entire vadose zone from soil surface to the water table. Pesticide processes represented in PRZM are similar to those in GLEAMS and include advection (or convection),dispersion, sorption, degradation in soil and on plant canopy, and plant uptake. PRZM can simulate the movement of multiple applications of pesticide and metabolites (daughter products) using long-term climatic data. Thus, the annual variation (time series) of pesticide leaching and runoff losses, as well as the effects of agricultural management cropping practices on the model predictions, can be determined.

AGNPS

AGricultural NonPoint Source pollution (AGNPS) model (Young et al., 1989) is an event-based watershed-scale model developed to simulate runoff, sediment, chemical oxygen demand (COD) and nutrient transport in surface runoff from agricultural watersheds. The model is distributed and operates on a uniform grid cell basis, which facilitates database creation and analysis of cumulative impacts. All model inputs are define at the cell level. The SCS curve number method is used to predict runoff volumes, and peak flow rate. Erosion and sediment transport are calculated using a modified Universal Soil Loss Equation (USLE) and Bagnold's stream power equation (sediment transport). Nutrient loss is calculated as a function of the nutrient content of the soil sediment, and an enrichment ratio. The AGNPS model was chosen for this study primarily because of its distributed nature.

ANSWERS

The Areal Nonpoint Source Watershed Environment Response Simulation model or ANSWERS (Beasely and Huggins, 1982) was designed as a planning tool for assessing the effects of land use, land management, and cultural practices on water quality (Beasley et al., 1980). ANSWERS is also a distributed, watershed-scale model that incorporates the spatially variable processes of runoff, infiltration, subsurface drainage, and erosion. Essentially, the model consists of two submodels which can predict hydrology and erosion responses from a given land management unit which are discretized into uniform grid cells. Recent modifications to the ANSWERS model include the addition of a sediment detachment/transport submodel that predicts sediment yield (Dillaha et al., 1988), and a chemical transport submodel that simulates phosphorus loading for each discrete grid cell (Storm, et al., 1988).

WEPP

The Water Erosion Prediction Project model (WEPP) (Gilley et al., 1988) was developed to provide a new generation water erosion prediction technology for use by agencies involved in soil and water conservation and environmental planning and assessment. The improved prediction technology is based on hydrologic and erosion science and the USLE. Three versions of the model have been proposed: a profile version designed for plot-scale analysis; a grid version structured towards the AGNPS model; and a watershed version designed to provide cumulative assessment of landscape influence on erosion process. The model is intended to correct some of the deficiencies of USLE, such as poor estimation of soil erosion rates on steep slopes. WEPP is a computer based model and contains soil, crop, and weather databases to facilitate model use. The effects of climate, soils, topography, and cropping systems on erosion, deposition and sediment transport can be simulated using the available soil and climate database.

GEOGRAPHIC INFORMATION SYSTEM

Background

Geographic information systems (GISs) are computer-based data management and display systems that are designed to work with spatial geo-referenced data and to manipulate large volumes of locational data derived from various sources (Burrough, 1986). GISs have become useful tools for solving spatial problems by working with certain kinds of data storage, manipulation, retrieval, and display within a database.

During the last two decades, the development in computer systems has made it easier to apply computer technology to store, manipulate, and analyze large volumes of spatial data, which increase the capability of GIS in data update, data analysis, and data integration. Hence, the primary functions of GIS are to: (a) integrate spatial and non-spatial data within a single framework; (b) offer a consistent framework for analyzing the spatial variation of processes across landscapes; (c) allow geographic data to be manipulated and displayed in a variety of forms including maps and tabular summaries; and (d) allow connections to be made between spatial entities based on geographic proximity and characteristics that are vital to understanding and managing land development activities and resources (Unwin and Wilson, 1990).

The operation of a modern GIS is the combination of hardware and software. Much of the hardware is fairly standard, but sophisticated graphic workstations are mostly used for data display and visualization. The software components consist of five major subsystems for:

A. Data input and verification: collect and/or processes spatial data derived from maps, remote sensors, direct digital inputs, etc.

B. Data storage and database management: stores, organizes, and manages the data rapidly in a database, and allows more than one users to work efficiently with and query the data.

C. Data manipulation and analysis: performs transformation needed to remove error from the data, append data as information becomes available, and also generate and spatially organize parameters for simulation modeling.

D. Data output and display: capable of displaying the data and the results of analysis to the user. The data may be presented as maps, tabular reports, and hard copy on plotters and printers.

E. User Interaction: provides the necessary interaction or interface between user and GIS proceeding through windows, icons, pop-up or pull down menus, and keyboard entries.

GIS Data Structure

To choose an appropriate data structure and data model is important in designing a GIS, especially in manipulation of spatial data to support modeling. In general, data can be stored in GIS as raster or vector. The object of interest in a raster data structure (e.g. soil types, land use/land cover, elevation) can be divided into a regular grid of cells in a specific sequence. The convectional sequence is row by row from upper left corner to lower right corner with each entry corresponding to the cell attribute (Figure 2). In vector data structure, discrete line segments or points are used to identify locations, such as boundaries, streams, and wells. Objects are created by connecting points with lines (arcs) from which attributes (e.g. area, perimeter) can be calculated (Figure 3). A raster data structure or sometimes called raster data model tells what occurs everywhere at each place in the area, while a vector structure model tells where everything occurs by giving a location to every object. The differences between these methods of encoding spatial information include: data volume, retrieval efficiency, data manipulation efficiency, data accuracy, and data display. In comparison of data volume, since unique values are stored for the entire area in raster structure, it will need lots of memory for data storage, and data retrieval. For data manipulation and analysis, the raster structure is more efficient than the vector structure model because the cell-based structure is easier to overlay, calculate, and encode in computer. The advantage and disadvantages of raster and vector data structures are summarized in Table 2.

Data Management

Data layer

The data for the study area can be recorded as a set of map layers. A map layer is a set of data describing a single characteristic for each location within a bounded geographic area, and only one item of information is available. As shown in Figure 4,

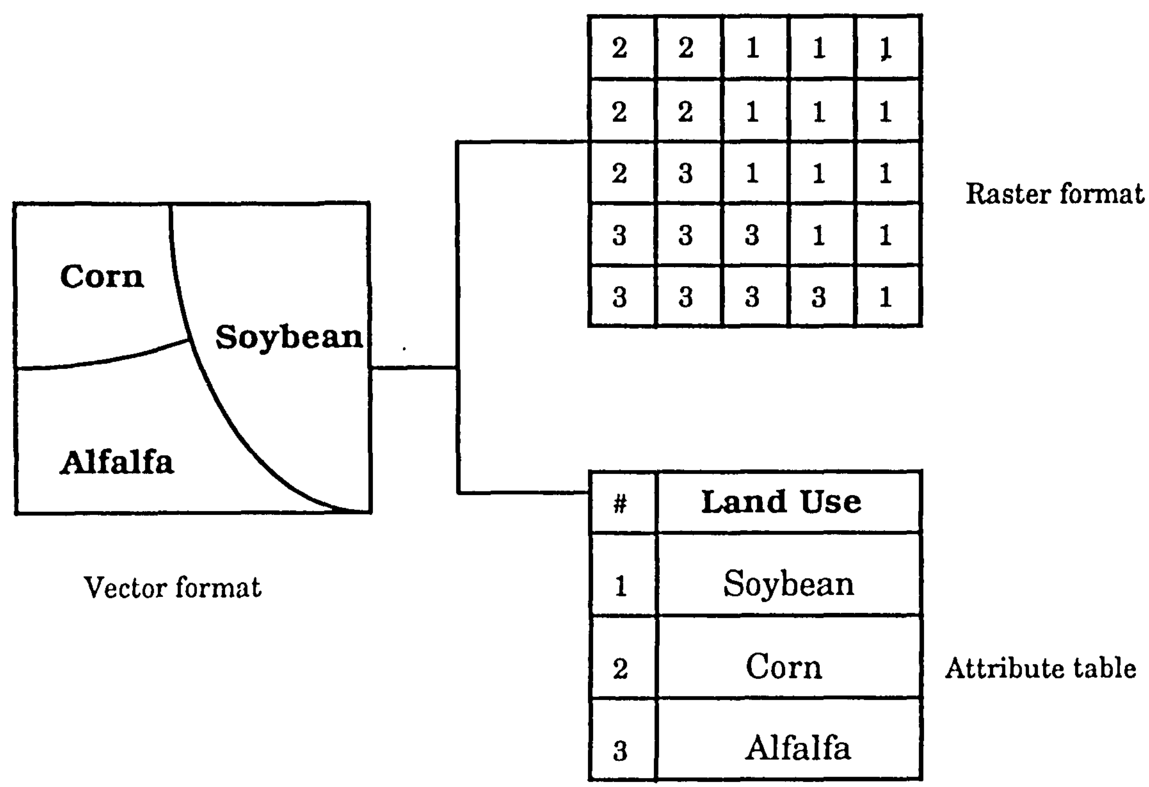
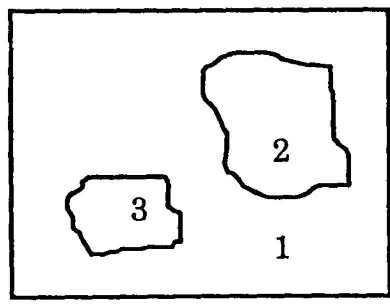


Figure 2. Relation among vector data, raster data, and attribute table



#	Area	Perimeter
1	652	.....
2	186	.....
3	94	.....

#	Land Use
1	grass
2	lake
3	pond

Figure 3. Combination of relational database and vector data

Table 2. Advantages and disadvantages of vector and raster GIS models

Model	Advantage	Disadvantage
Vector	1. Compact data structure 2. Accurate graphics 3. Good representation of data structure	1. Complex data structure 2. Simulation is difficult 3. Spatial analysis within polygons are impossible
Raster	1. Simple data structure 2. Various kinds of spatial analysis are easy 3. Simulation is easy	1. Volumes of graphic data 2. Raster maps are not so accurate 3. The use of large cells to reduce data volumes can be a serious loss of information

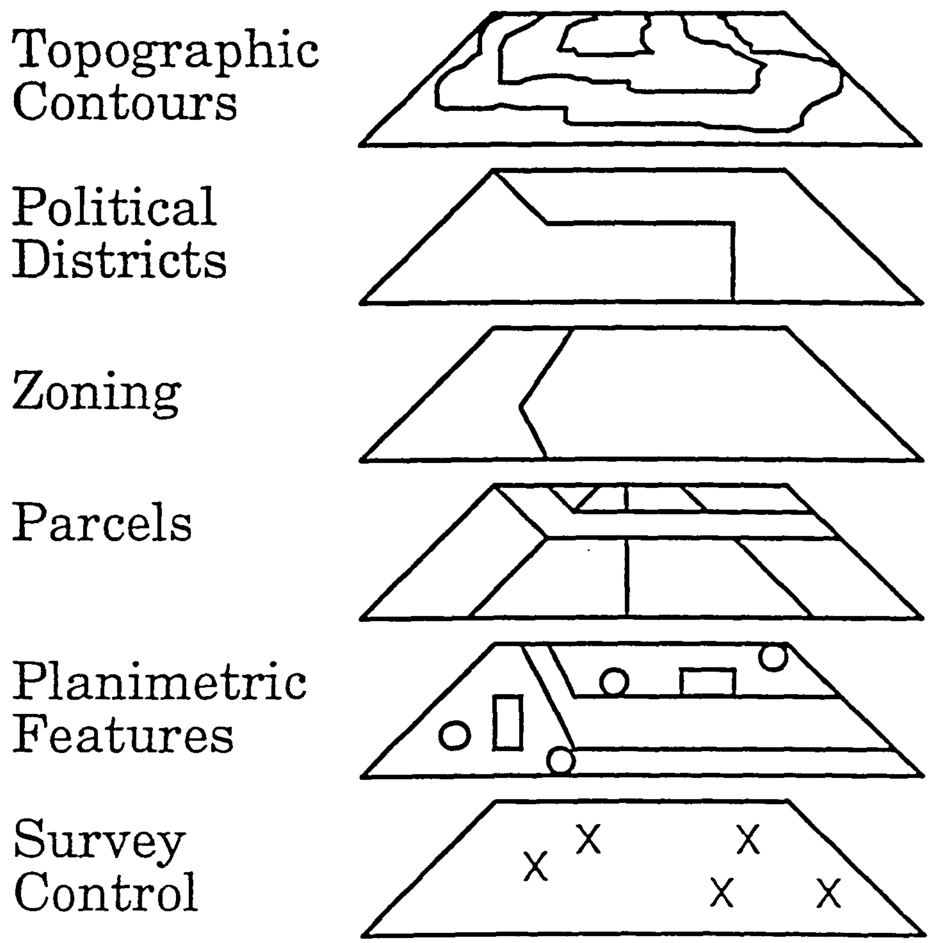


Figure 4. Data base layering concept (Antenucci et al., 1991)

each layer is a set of homogeneous feature. The major purpose of the separation is to simplify the combination of features for display, and analysis.

Database Management System

A database management system (DBMS) is the software that permits one or more users to work efficiently with data in a database, which is a structured collection of information on a object. A DBMS is like a high level computer language and also provides a interface between users and system. The attribute data associated with different data layer can be stored and maintained in DBMS, which will provide users with the necessary input/output routine so that the database can be accessed as required. The capabilities of DBMS are to (1) define the contents of the database; (2) insert new data and delete old data; (3) ask about the database contents; and (4) modify the contents of the database.

Data manipulation and analysis

Data manipulation includes a standard set of arithmetic functions, five value selection modes, and three mapping functions. The arithmetic functions are add, subtract, multiple, divide, square root, exponential, trigometric function, and logarithms. The value selection modes are equal, greater than, less than, greater than and less than, and less than or greater than a value. The mapping functions, union, intersection, or exclusion, provides the capability of combining any number of individual data layer with any number of data layer (Walsh, 1985). Data from original map can be transformed to the digital format either by digitizing or scanning, then the grid map can be generated by grid overlay. Same procedures can be provided on those thematic maps of interest andcreate a composite map by overlay (Figure 5).

Both the selection modes and mapping functions can generate a new data set from the original data. While the mapping function will allow users to place conditional restrictions on the data sets with one of the five relation modes, and then produce a new output data set or map.

After the processes, these thematic maps of interesting will be encoded and stored in raster or vector data structure. Some of derived data also can be obtained by relating to the numeric values from thematic data. For examples, the hydrologic curve number, Manning's roughness coefficients, surface condition constants, and cropping factors can be used to calculate many hydrologic processes, including infiltration and runoff rates. Applying those data to simulation model, output will be obtained after analyzing the entire study area. As shown in Figure 6, the potential soil erosion can be obtained by overlaying and analyzing both the original land data, topography, soils, land use etc, and the derived data, slope, runoff, and erodibility.

Application

The use of geographic information systems technology has increased considerably during the past decade. Both the federal and state government agencies have been impacted by this technology. At the federal government level, the following ten general uses of GIS have been identified (Antenucci et al., 1991):

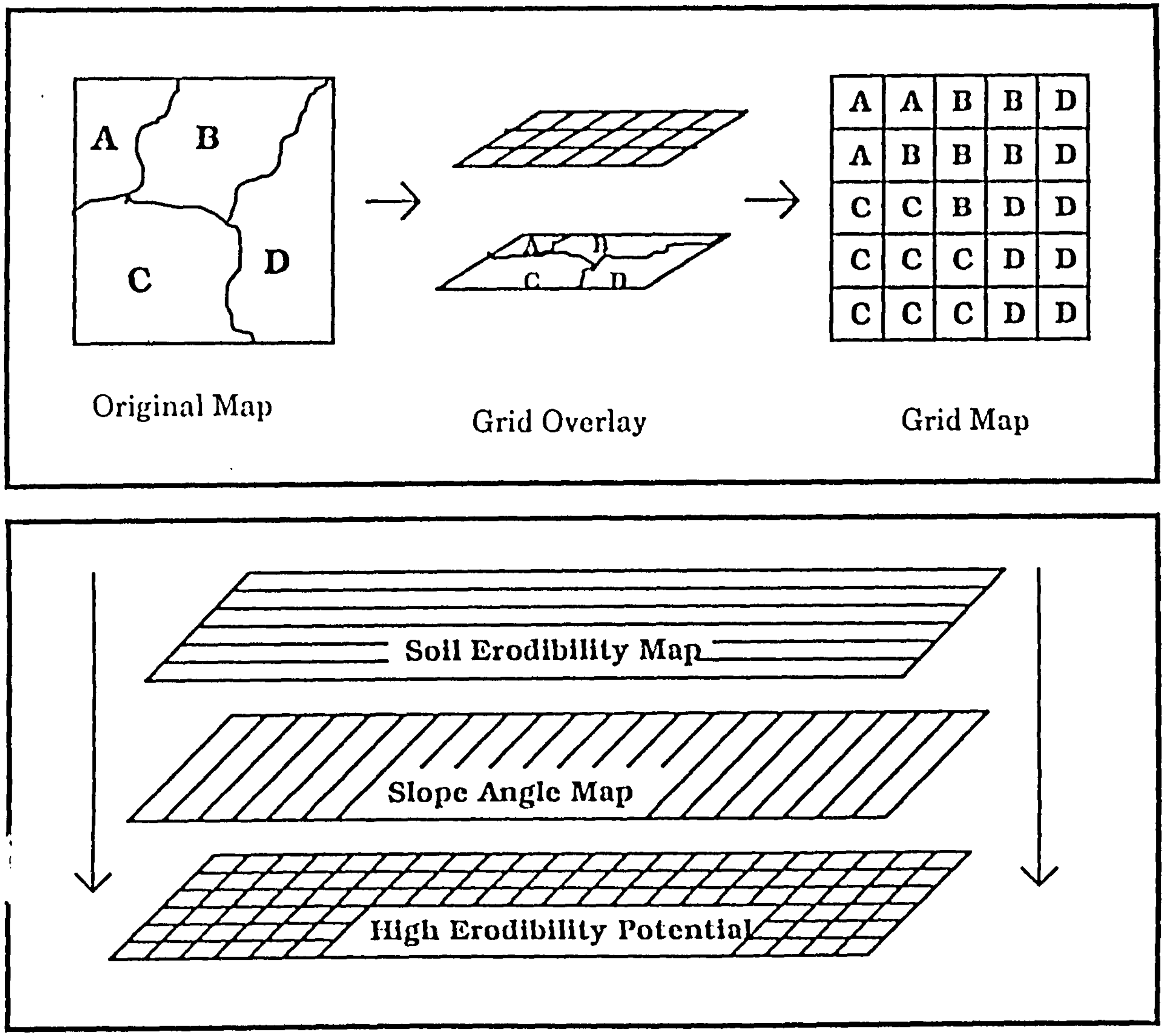


Figure 5. Data transformation from original map to grid map (top), Data overlaying for composite mapping (bottom) (Walsh, 1985)

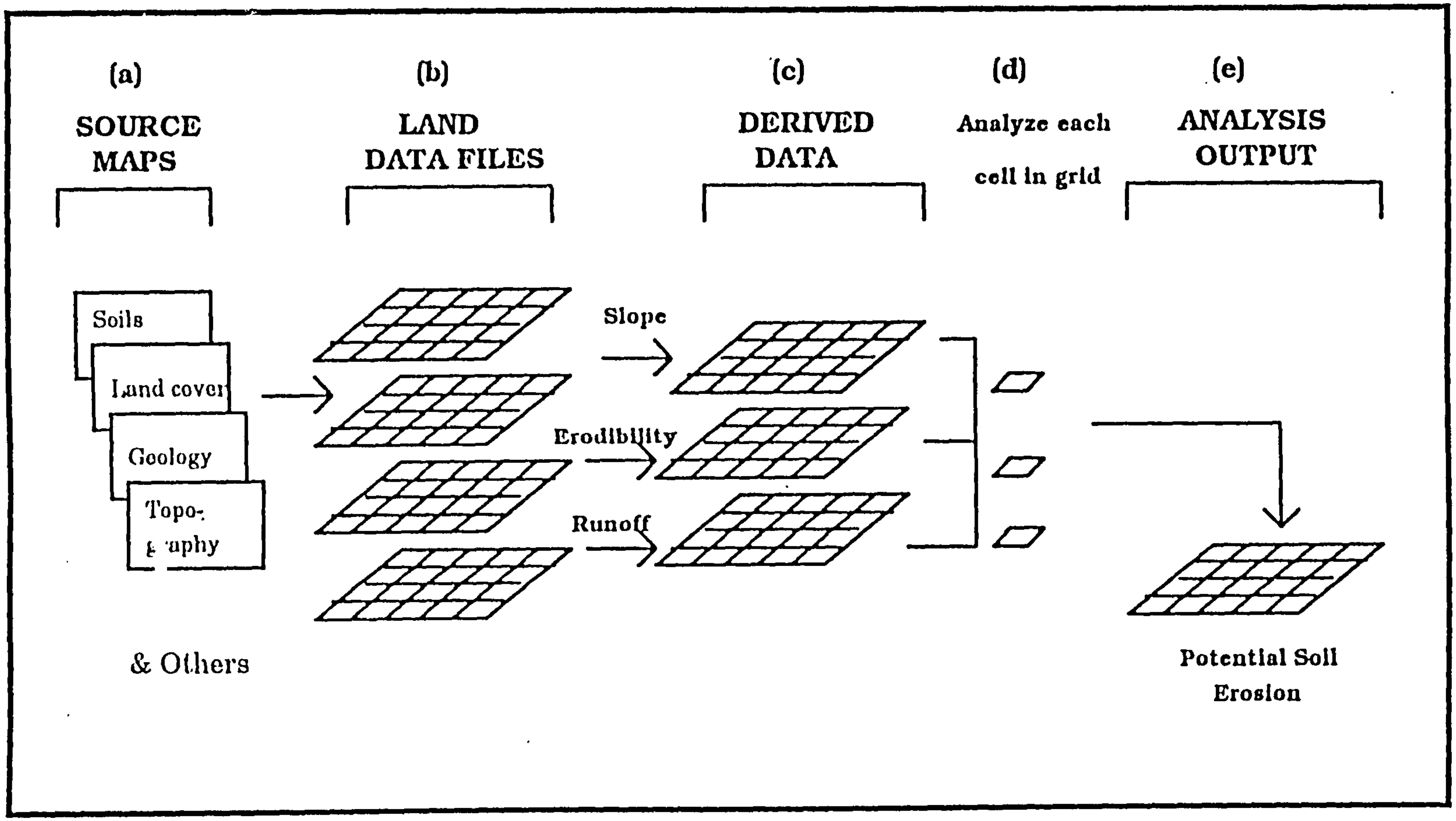


Figure 6. Analysis procedure using geocoded data (Walsh, 1985)

A. Environmental assessment and monitoring - Environmental impact analysis, irrigation engineering, pollution studies, soil conservation and flood mapping.

B. Land and water resource inventory, planning, and management - site design and screening, road design, land management, wetland maps, and water quality and quantity studies.

C. Terrain map - Topographic maps, elevation models, slope maps, and aspect maps.

D. Base map development - Analysis, plotting, modification, marine information, ocean surveys, and navigation.

E. Thematic map data - Socioeconomic, soil, and other characteristics at the state, county, and congressional district levels.

F. Data display and analysis - Map data access and display, merging and integrating data bases, and image maps.

G. Network simulation models - National rail Network Model and National Rail Defense Essential Network.

H. Navigation systems - Air traffic control systems, inflight navigational data, and nautical cartographic data.

I. Mineral resource assessment - Geologic maps, mineral and mineral fuel resource assessment.

J. Trainers and simulators - Radar trainers and flight simulators.

In state governments, at least forty-five states are using a GIS or a related spatial system in at least one state agency, and at least thirty-four states have more than one geographic information system. States' uses include:

A. Transportation - Road design, highway mapping, pavement and maintenance management, capital budget planning, analysis of accident data and traffic volumes, and routing and dispatching vehicles.

B. Management of nature resource and landuse - Public policy decisions regarding lands and water, natural resources, fish and wildlife inventories, planning and management, and environmental assessment; development of minerals, coal, oil and gas, and timber resources; land use plans, environmental regulatory programs, and historical and cultural resources management.

Local government has numerous and diverse uses for GIS. Systems are not used only by agency managers and employees, but also by elected officials, attorneys, developers, financial institution, and the general public. As shown in Figure 7, the cooperative programs between cities, counties and utilities includes : tax assessment and collection, maintenance of property records, dispatch of emergency service vehicles, traffic engineering, operation of public works and utilities, road maintenance, map production.

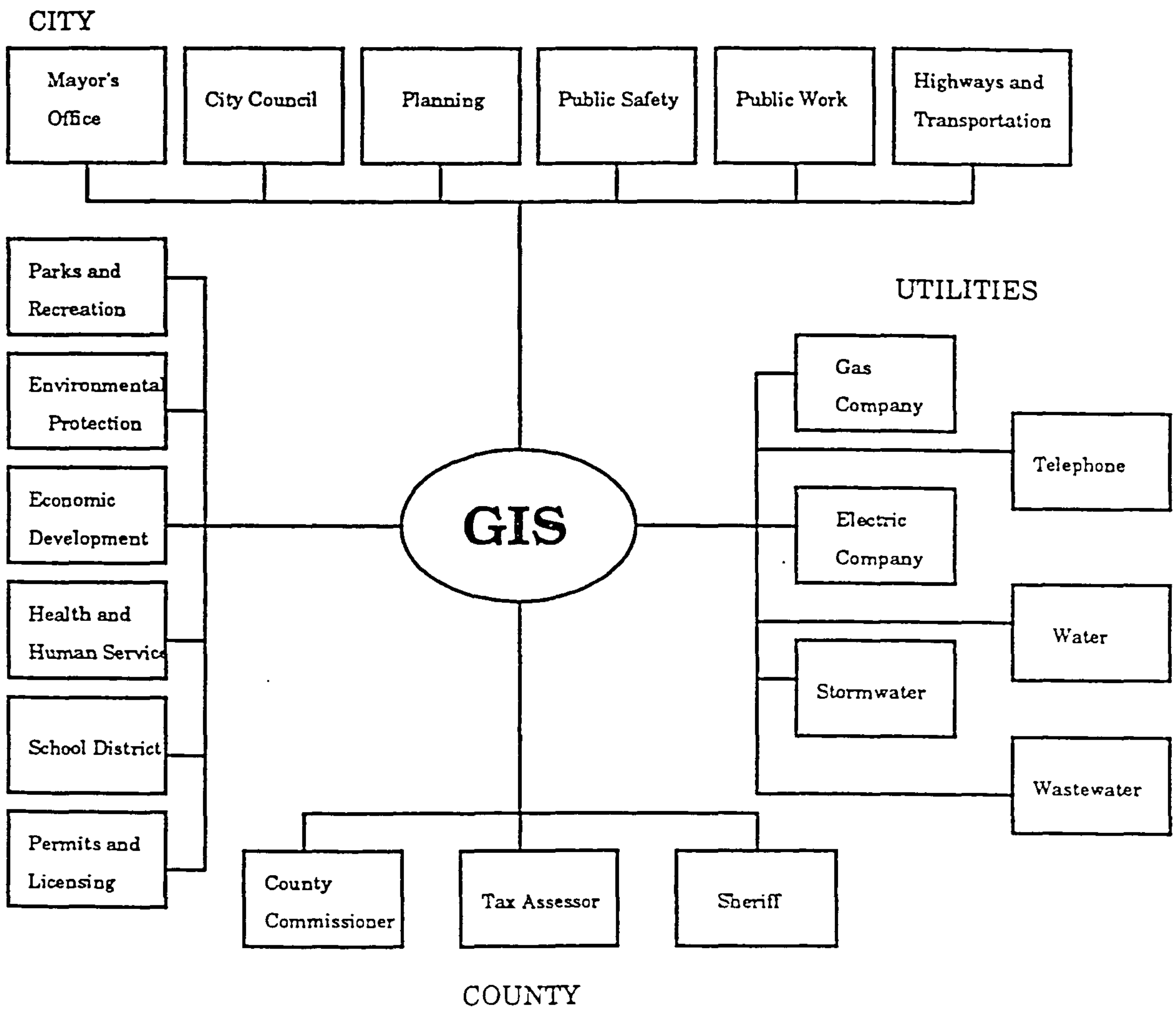


Figure 7. Cooperative programs between cities, counties, and public and private utilities.

In the water quality modeling area, four primary roles of a GIS can be identified (Joao and Walsh 1992; Bathurst and O'Connell 1992). A GIS can:

A. Perform complex manipulation and analysis of spatial and non-spatial data for the development and preparation of data inputs to models.

B. Provide the linkage mechanisms between models having different spatial representation.

C. Facilitate the conversion and standardization for digital landform of different scales and projections.

D. Allow for post-simulation graphics output display and spatial analysis for evaluating model results.

The GIS used for this study is ESRI's ARC/INFO revision 6.1 (ESRI, 1992). In ARC/INFO system, information is stored as areas (polygons), lines (arcs), or points by using relational database that link attributes to features and stores the information in hierarchical computer files called coverage. The system provides function for: (a) digitizing, editing, and reformatting data; (b) reporting output in different features, such as map and table; and (c) using spatial operation for topological overlay, buffer creation, and spatial query. In water quality modeling, the ARC/GRID module is a very power sophisticated module for data management and analysis.

INTERFACE BETWEEN MODELS AND GIS

MODEL: AGNPS

AGNPS Input Data Structure

Since AGNPS is a cell-based model, all the model parameters are defined at the cell level. A total of 20 different parameters are required for simulating impacts of agricultural management systems on water quality. Table 3 summarized the parameters required for the entire watershed and for each grid cell. Many of these parameters can be obtained from local planning offices, look-up tables in the user's manual, and derived by relating to some other parameter. For example, some of the input parameter required of the model including , the SCS curve number, Manning's roughness coefficient, and surface condition constant, which are influenced by many hydrologic process, such as infiltration and runoff.

The AGNPS model is a grid based model which makes it useful for accommodating spatial variable problems and provides a good candidate for GIS application. The grid cells in AGNPS are uniform square areas having unique attributes for specific spatial features of the watershed landscape. In establishing the model input data file, the entire watershed is divided into cells with user-defined resolution. The cells are numbered sequentially from the northwest corner to south east. Then, the watershed drainage pattern aspect is established to identify the direction of flow leaving a cell (Figure 8). The drainage direction consists of 8 possible directions (Figure 9) encoded as number

Table 3. AGNPS input data file content

Item	Data
	Watershed Input
1	Watershed identification
2	Cell area (acres)
3	Total number of cells
4	Precipitation (inches)
5	Energy-intensity value
6	Rainfall duration
7	Storm type
	Cell Parameter
1	Cell number
2	Number of the cell into which it drains
3	Aspect
4	SCS curve number
5	Average land slope (%)
6	Slope shape factor (uniform, convex, or concave)
7	Average field slope length (feet)
8	Manning roughness coefficient for the channel
9	Soil erodibility factor (K) from USLE
10	Cropping factor (C) from USLE
11	Practice factor (P) from USLE
12	Surface condition constant (based on land use)
13	Soil texture (sand, silt, clay, peat)
14	Fertilization level (zero, low, medium, high)
15	Fertilization availability factor(% fertilizer left in top 1 cm of soil)
16	Point source indication (indicated existence of a point source input within a cell)
17	Gully source level
18	Chemical oxygen demand factor
19	Impoundment factor (indication presence of and impoundment terrace of an impoundment terrace system within the cell)
20	Channel indicator (indication existence of a defined channel within a cell)

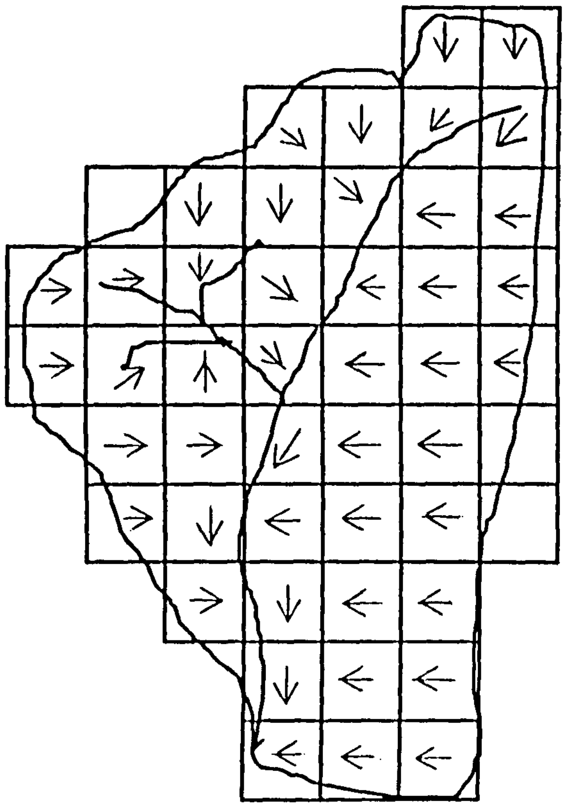


Figure 8. Watershed division in AGNPS
(Young et al., 1987)

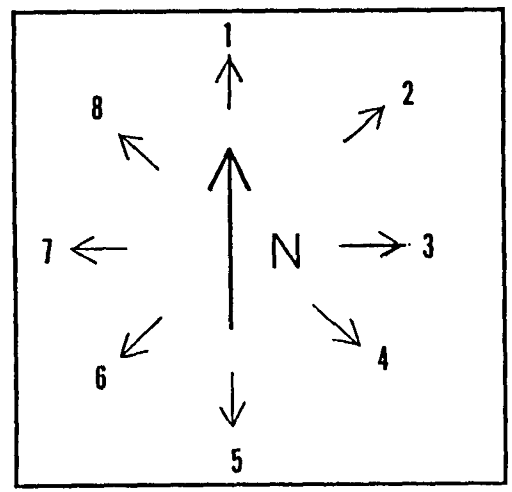


Figure 9. Eight possible drainage directions
(Young et al., 1987)

from one to eight. This numbering system facilitates the development of an interface program to assist modeling efforts. Figure 10 shows the standard format for input file which can be imported from an ASCII text file. During the execution of AGNPS, a GIS output (Figure 11) can be generated and stored as an ASCII text file. The cell-by-cell output file generated can represent sediment loading, soil loss, nutrient export or any other parameter simulated by the model (see Table 4).

GIS : ARC/INFO

The ARC/INFO GIS software (ESRI 1992) was used in establishing the link between AGNPS and spatially variable data. ARC/INFO is one of the most popular commercial software which successfully combines the standard relational database management system (INFO) to handle attribute tables with the software to handle objects stored as arcs (ARC). The "ARC' portion manages the spatial data, such as points, lines and polygons, while the "INFO" part deals with the accompanying nonspatial attribute data. Figure 12 shows the major function of ARC/INFO.

In the ARC/INFO GIS, data stored in the vector format can be transferred into raster format for distributed parameter modeling. Commands such as like POLYGRID, LINEGRID and POINTGRID can be used to convert polygons, lines, and points data, respectively, into equivalent grid data. Then, using "GRIDASCII", the grid data are then transformed into ASCII file format which can be imported into a model. Figure 13 shows the ARC/INFO ASCII format, which includes the X minimum and Y minimum coordinates of map, number of row and column for grid, nodata value which can be name of watershed

```
UPPER BLUE GRASS WATERSHED

2.5  413   4.7  68.0     2  24.0I    1ha (2.5 ac) cell size

1000  5000  4  78  1.0  1  2000.0800.280.23  1.000.05  2  2  50  0   0  170
2000  5000  5  78  1.0  1  2000.0800.280.23  1.000.05  2  2  50  0   0  170
3000  6000  5  78  8.0  1  1750.0800.280.23  1.000.05  2  2  50  0   0  170
4000  5000  3  78  2.0  1  2000.0800.300.23  1.000.05  2  2  50  0   0  170
5000 11000  4  78  2.0  1  2000.0800.280.23  1.000.05  2  2  50  0   0  170
.....
```

cell size; total cell #; precipitation; R index; watershed description

cell number & receiving cell #; aspect; SCS #; topology parameter; nutrient parameter; channel indicator

Figure 10. ASCII format of AGNPS input file

```
******* GIS SOIL LOSS OUTPUT *******

1 000  3  2.46  .00  0  2.46  13   .0   .70  .00  1.74 1.43  18
2 000  3  2.46  .00  0  2.46  13   .0   .70  .00  1.74 1.43  18
3 000  3  2.46  .00  0  2.46  13   .0  5.77  .00 14.43 3.31  77
4 000  3  2.46  .00  0  2.46  13   .0  1.16  .00  2.91 1.62  44
5 000 10  2.46 2.46 34  2.46  27 1.09 4.49  .00  2.71 7.48  -4
.....

******* GIS NUTRIENT OUTPUT *******

1 000  3  2.37 2.03 2.27 2.27  4 1.19 1.01 .44 .44  1 95.00 94.69 170
2 000  3  2.37 2.03 2.27 2.27  4 1.19 1.01 .44 .44  1 95.00 94.69 170
3 000  3 12.86 3.96 2.27 2.27  4 6.43 1.98 .44 .44  1 95.00 94.69 170
4 000  3  3.57 2.24 2.27 2.27  4 1.78 1.12 .44 .44  1 95.00 94.69 170
5.000 10  3.38 2.51 2.27 2.27  4 1.69 1.25 .44 .44  1 95.00 94.69 170
.....
```

Figure 11. ASCII format of AGNPS GIS output file

Table 4. AGNPS output GIS data file content [a]

Item	Data
	GIS Soil Loss Output
1	Cell number
2	Drainage area (acre)
3	Runoff volume (in)
4	Upstream runoff (in)
5	Peak flow upstream (cfs)
6	Downstream runoff (in)
7	Peak rate (cfs)/Peak flow downstream (cfs)
8	Runoff generated above (%)
9	Cell erosion (t/a)
10	Sediment generated above (tons)
11	Sediment generated within cell (tons)
12	Sediment yield (tons)
13	Sediment deposit (%)
	GIS Nutrient Output
1	Cell number
2	Drainage area (acre)
3	N-loss in sediment within cell (lbs/a)
4	N-loss in sediment at cell outlet (lbs/a)
5	N-loss in water soluble within cell (lbs/a)
6	N-loss in water soluble at cell outlet (lbs/a)
7	N-loss in water soluble, concentration (ppm)
8	P-loss in sediment within cell (lbs/a)
9	P-loss in sediment at cell outlet (lbs/a)
10	P-loss in water soluble within cell (lbs/a)
11	P-loss in water soluble at cell outlet (lbs/a)
12	P-loss in water soluble, concentration (ppm)
13	COD in water soluble within cell (lbs/a)
14	COD in water soluble at cell outlet (lbs/a)
15	COD in water soluble, concentration (ppm)

[a] t/a = tons/acre; lbs/a = pounds/acre;
ppm = part per million (1 ppm = 1 million/liter)

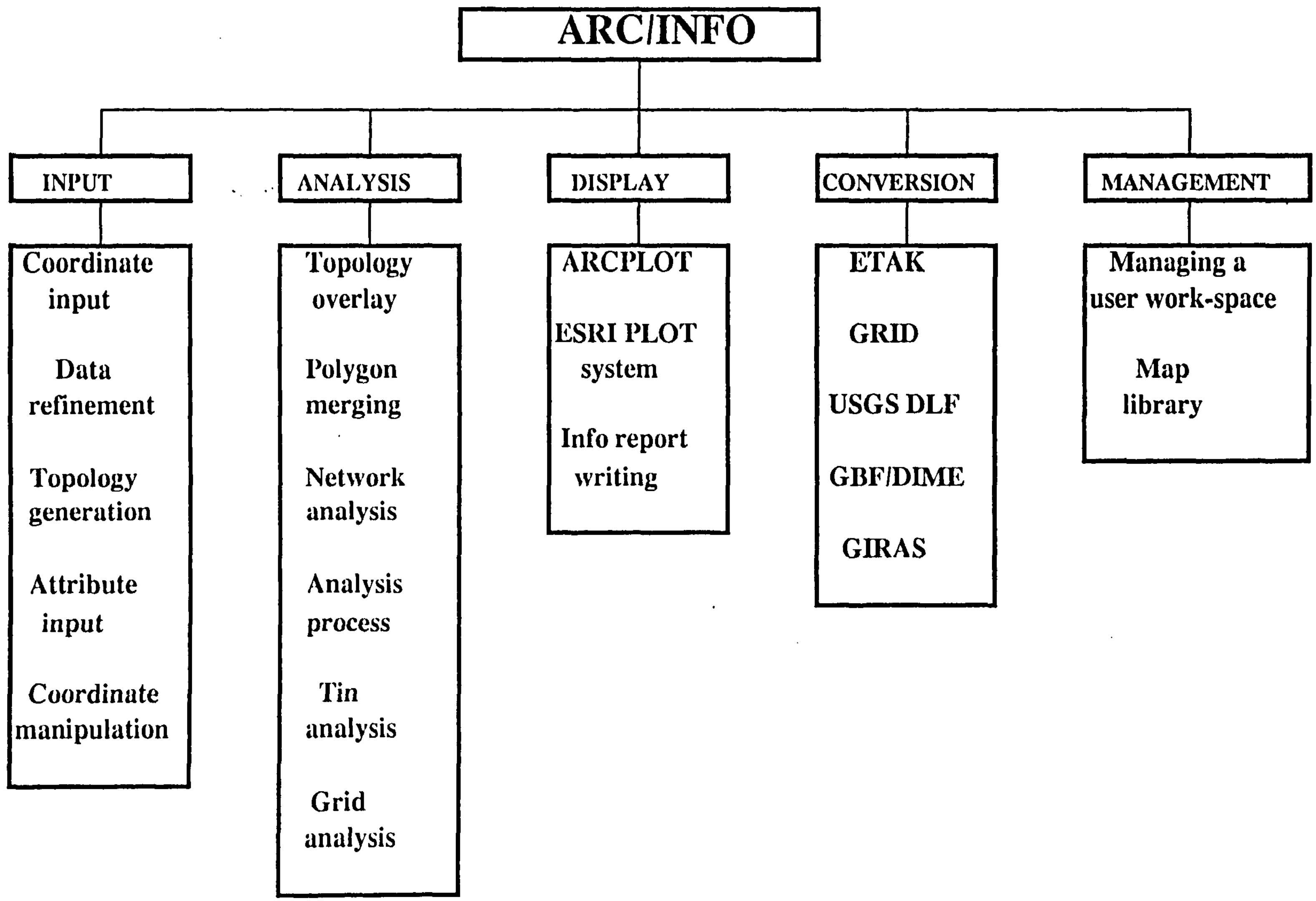


Figure 12. Major functions of ARC/INFO

```
ncols          31
nrows          26
xllcorner      339012.0625        information about data
yllcorner      4627972.5
cellsize       100
NODATA_value   -9999

26    -9999 -9999 -9999 -9999 -9999 -9999 1 1 1 1 2 2 1 1 1 2 3 4 5 6 3 3 2 1 2 2 2 1 -9999 -9999
rows  -9999 -9999 -9999 2 3 1 1 1 3 5 6 -9999 -9999 4 3 2 6 8 -9999 -9999 2 3 4 5 1 2 2 1 11 -9999
      .....
      -9999 -9999 -9999 -9999 -9999 -9999 1 1 1 1 1 1 1 2 3 5 6 5 4 3 3 3 1 2 -9999 2 2 3 5 1 -9999

          31 columns

       coordinate ( 339012.0625, 4627972.5 )
```

Figure 13. ARC/INFO ASCII format from GRIDASCII

specified for those area outside the study area, and the raw data.

AGNPS-ARC/INFO Linkage

The linkage between the AGNPS model and ARC/INFO GIS was established through the development of "special-purpose" computer programs or interfaces. The interfaces provide the capabilities for data file conversion between AGNPS and ARC/INFO, based on raster data structure. In ARC/INFO, the vector data can be converted and stored as grid (raster) structure. And then, GRIDASCII rewrites the raster data for each cell to the ASCII format which will be the source input/output file for the interface. The components of the interface shown in Figure 14 through Figure 16 are described in the following sections.

File conversion

Watershed boundary The watershed boundary file from ARC/INFO is defined as 1 for the inside the boundary, and 0 otherwise (Figure 17). This file is required in determining the cell number, receiving cell number, X_minimum, Y_minimum, number of rows and columns, and nodata value. All of which are useful during the transformation of AGNPS model output file back to ARC/INFO text file.

Cell number Based on the watershed boundary file, all the cells inside boundary are numbered starting with 1 at upper left corner to lower right corner automatically. Here, N is the total number of grid cells within the watershed boundary.

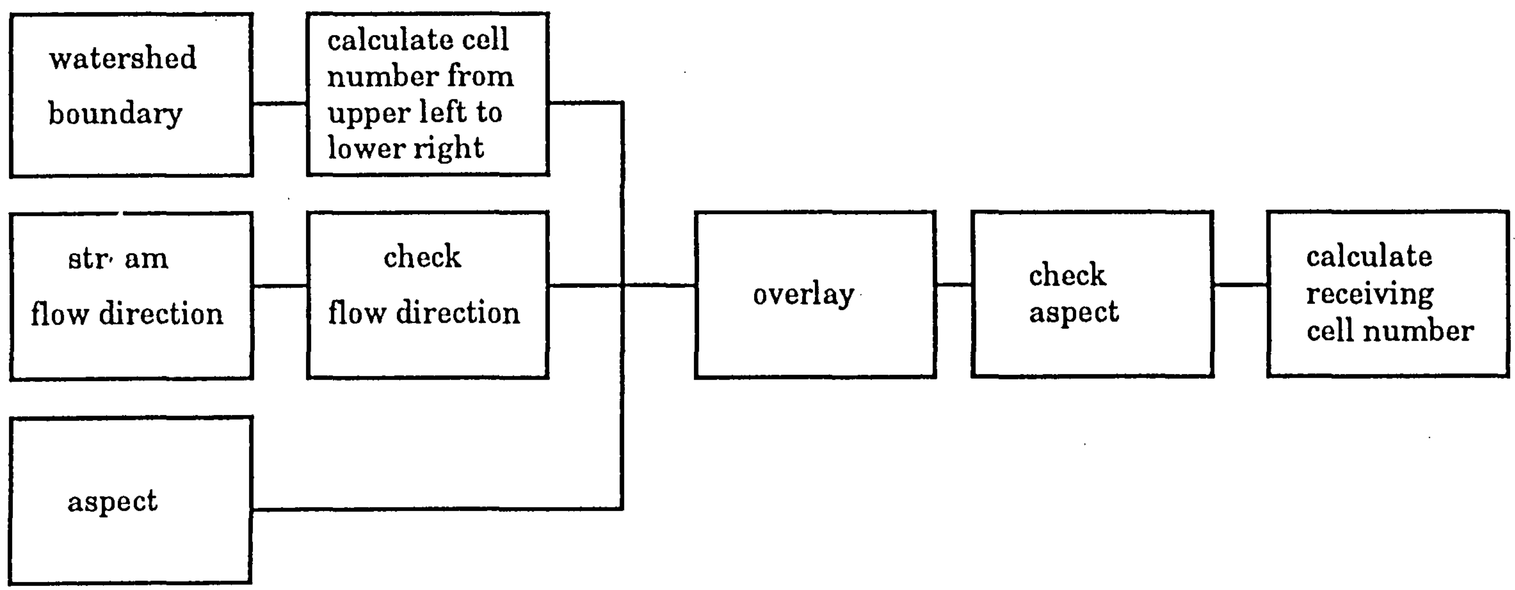


Figure 14. File conversion (Interface -- Part I)

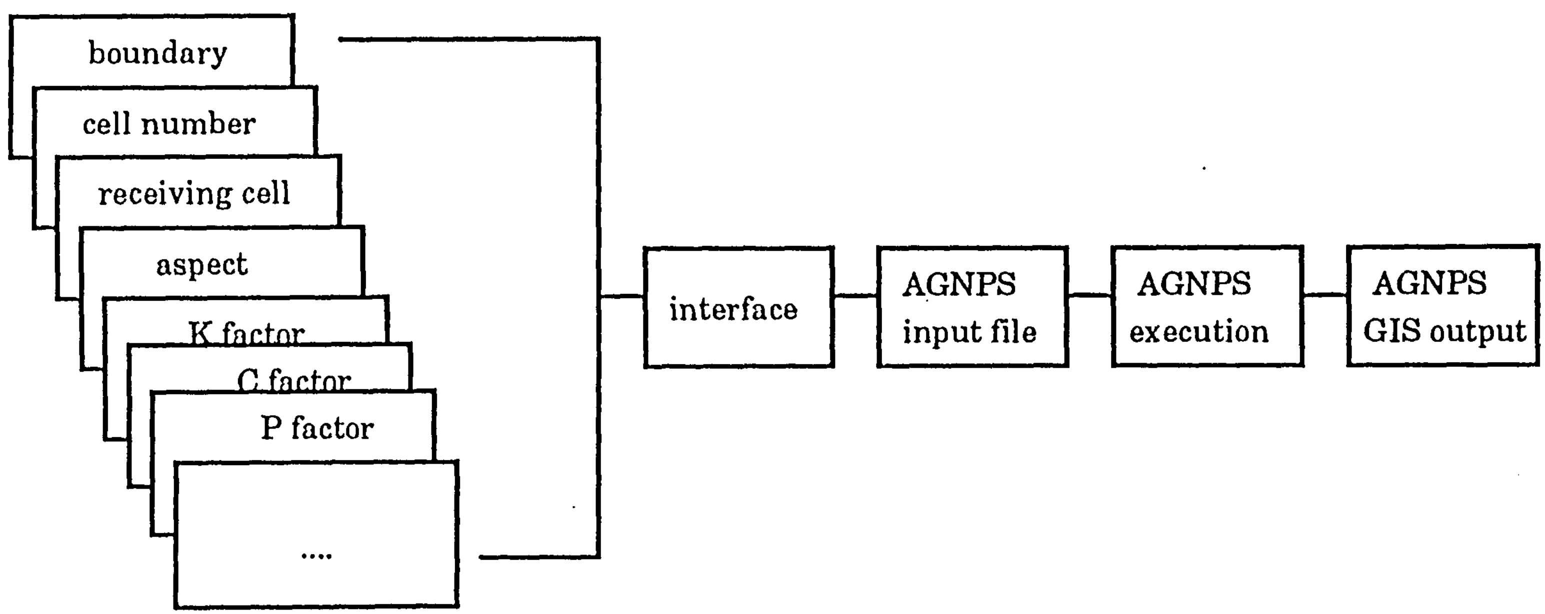


Figure 15. ARC/INFO to AGNPS: assembly of input data (Interface -- Part II)

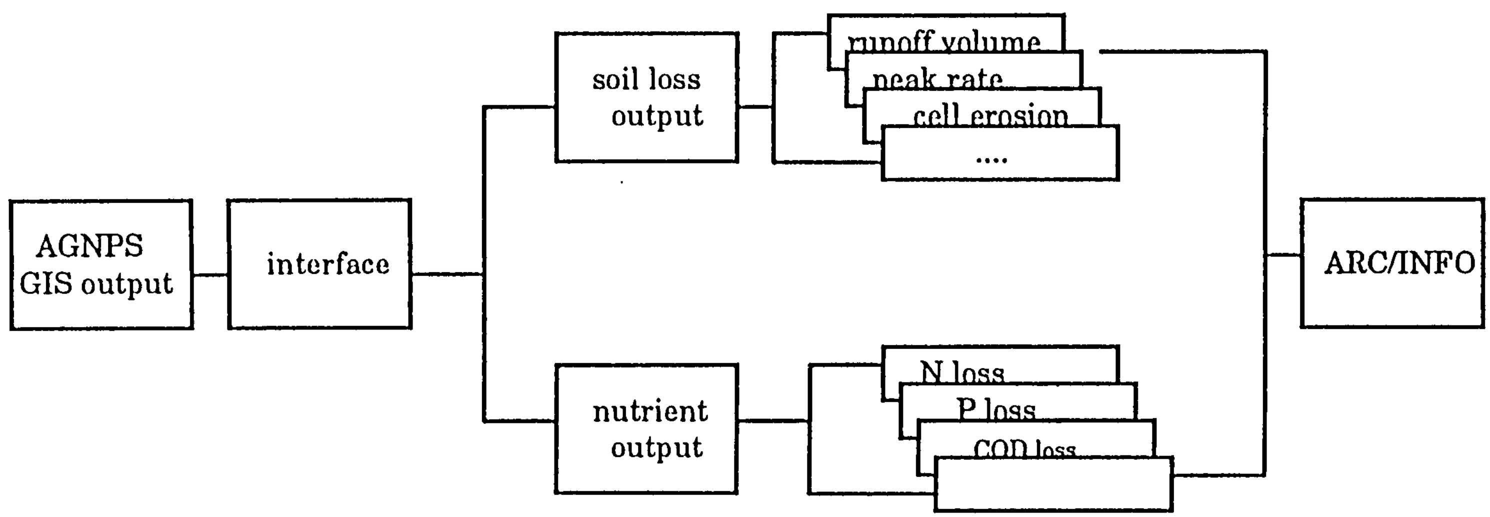


Figure 16. AGNPS to ARC/INFO: analysis of output data (Interface -- Part III)

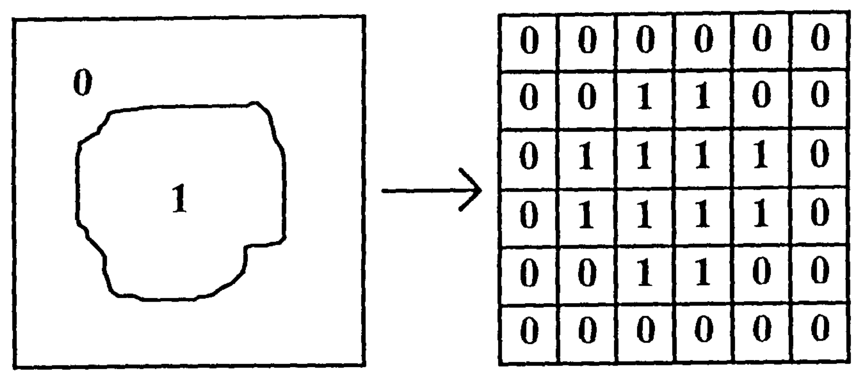


Figure 17. Watershed boundary encoding

Flow direction and aspect The algorithm developed for determining channel flow direction parameter used in flow routing and aspect is as follows. First, a file which stores the flow direction of the stream is checked by the program. If the direction indicates the stream will flow outside the boundary or outside the stream, the program will search around neighborhood cells to find the correct direction (see Figure 18). Second, the flow direction file is overlaid on aspect file generated by the ARC/INFO GIS. And according to the boundary range, a check is made using the aspect. If the

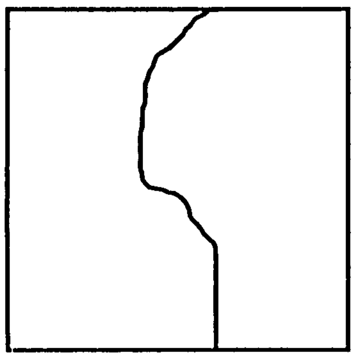
aspect at the boundary cell is directed outside the watershed, the program will also search neighborhood cells to determine the correct aspect (Figure 19). Then, based on the flow direction of stream and the aspect, a search is performed for the watershed outlet cell (control point).

Receiving cell The receiving cell and cell is determined number for each cell using aspect and cell number coverages.

File transformation In order to save the memory space, all the ASCII input text file are stored as integers, or file of real.

ARC/INFO GIS to AGNPS : Assembly of input data

In the AGNPS model, 21 parameters are required for each cell, considered homogeneous with respect to hydrologic/land management characteristics. Some of these parameters are not derived using GIS techniques, reasonable default values can be specified or actual values can be entered in ASCII file format (Table 5). Some of them



vector format

0	0	6	6	0	0
0	0	5	0	0	0
0	0	5	0	0	0
0	0	4	0	0	0
0	0	4	4	0	0
0	0	0	5	0	0

grid format

0	0	5	6	0	0
0	0	5	0	0	0
0	0	5	0	0	0
0	0	4	0	0	0
0	0	4	5	0	0
0	0	0	5	0	0

after checking

Figure 18. Flow direction checking

0	0	6	6	0	0
0	0	5	0	0	0
0	0	5	0	0	0
0	0	4	0	0	0
0	0	4	4	0	0
0	0	0	5	0	0

stream

→

2	4	6	6	6	8
3	4	4	7	7	4
4	5	3	6	5	8
5	3	4	5	6	1
5	4	4	4	5	8
4	2	3	5	7	7

aspect

→

3	4	6	6	6	7
3	4	5	7	7	5
4	5	5	6	5	8
5	3	4	5	6	1
5	4	4	4	5	8
3	2	0	5	7	7

overlay and check

Figure 19. Aspect checking and overlay

Table 5. Parameters required in interface

Item	Parameter	Input format [a]
1	Watershed boundary	F
2	Aspect	F
3	Cell number	F
4	Receiving cell number	F
5	Cropping factor (C)	F
6	Channel indicator	F
7	Soil erodibility (K)	F,S
8	Slope	F,S
9	SCS curve number	F,S
10	Slope shape	F,S
11	Slope length	F,S
12	Mannings roughness coefficient	F,S
13	Cropping practice factor (P)	F,S
14	Surface condition constant	F,S
15	Soil texture	F,S
16	Fertilization level	F,S
17	Fertilization availability factor	F,S
18	Point source indicator	F,S
19	Gully source level	F,S
20	Chemical oxygen demand factor	F,S
21	Impoundment factor	F,S

[a] F = ARC/INFO ASCII file; S = Single value

are required to be derived in GIS. Such AGNPS model parameters include boundary, cell number, receiving cell number, aspect, cropping factor (C), and channel indicator. Other input parameters are supplied by the GIS.

AGNPS to GIS : Analysis of output data

During the execution of AGNPS, a GIS output can be generated (this option is available in AGNPS). Depending on the user-defined modeling objective, the GIS output file can be separated into different files (e.g. soil loss and nutrient output). In order to generate an ARC/INFO ASCII file, the x minimum, y minimum, number of rows and columns, and nodata value are required. Recall the procedure in File Conversion, when the watershed boundary file from ARC/INFO was created. Since these information already exist, they can be used to direct model output data conversion from AGNPS.

Once the output files in ASCII format are generated in ARC/INFO compatible format, the ASCIIGRID command (in ARC/INFO) can be employed to convert them to grid (raster) structure and, in term, to a vector format if desired using POLYGRID command. There are twelve parameters in AGNPS soil loss output, and fourteen in nutrient output. The same process is repeated to convert all the output parameters of interest to ARC/INFO, for display in ARCPLOT, or any desired form using Arc Macro Languages (AML) (Figure 20).

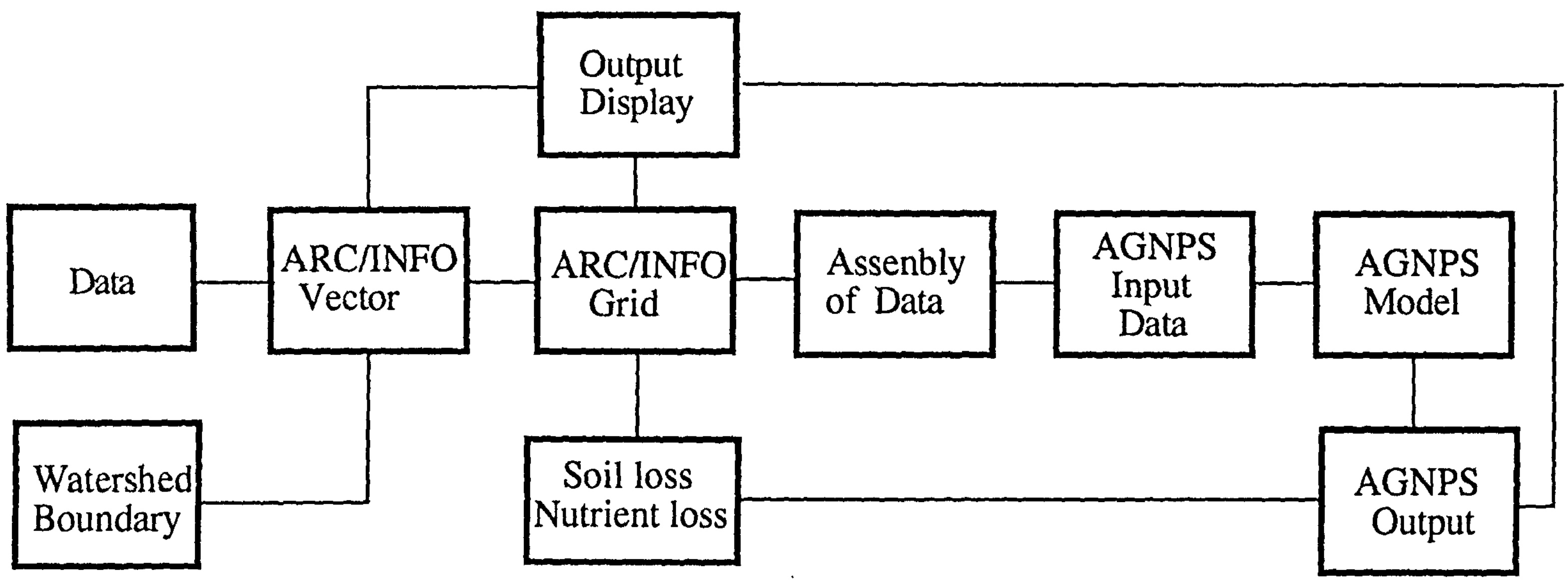


Figure 20. Flow diagram of the integration between GIS and AGNPS

EXAMPLE APPLICATION

Description of Study Area

In this study, one watershed was chosen to demonstrate the utility of the interface program and statistical analysis procedure detailed in this study. The study watershed is located in Southern Iowa and was chosen because of the availability of digital (spatial and non-spatial) data. The characteristic of the watershed is described below.

Lake Icaria watershed

The Lake Icaria watershed is located in Adams County in southern Iowa. The total area, which contributes flow to Lake Icaria is 17.475 ha. Average annual rainfall is 33 inches with the greatest amount of 5.5 inches occurring in June. Agricultural production in the watershed consists of row crops integrated with livestock (hog, beef cattle, poultry, sheep) production enterprises. The agricultural land use consists of 49% cropland,and 22.4% pasture, while 11.6% of the area is under the Cropland Reserve Program (Figure 21). About 4.6% of the watershed area is either non-farmable or unsuitable for pasture. The remaining 12.5% of watershed is occupied by water (principally Lake Icaria with surface area of 2182 acres), farmsteads, road, and parkland.

Water quality and nonpoint source pollution within the watershed have been the major research interests. A water quality survey conducted in 1986 by the University of Iowa Hygienic Laboratory showed Lake Icaria to be eutrophic and moderately productive (relative to aquatic life). The degradation in Lake water quality reason was

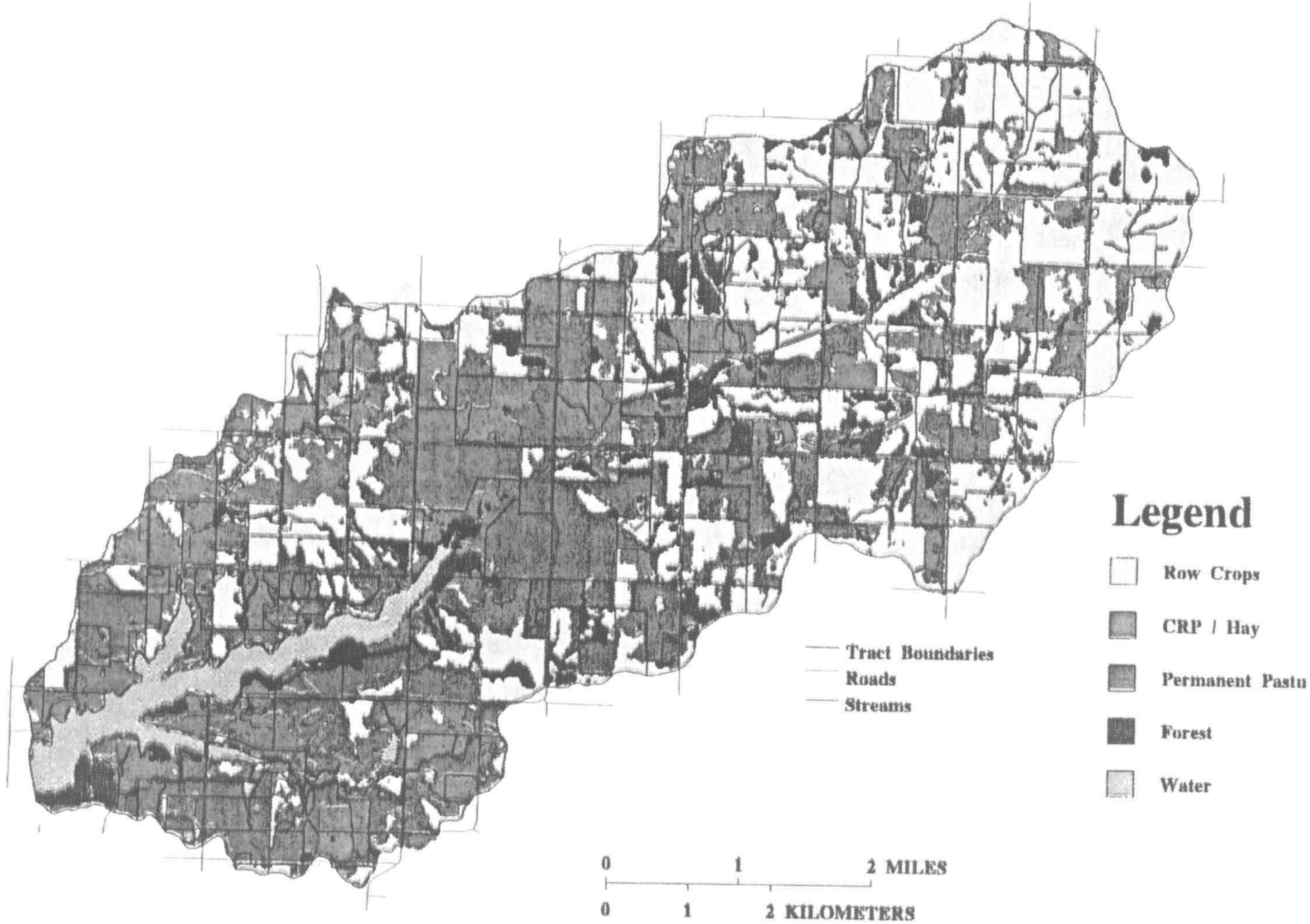


Figure 21. Lake Icaria Watershed : Land use

traced to nonpoint sources from agricultural activities (cropping and livestock production), particularly nutrients from cropland. In general, the study indicated that nonpoint source pollution problem can be directly linked to sheet and rill erosion, gully and streambank erosion, intensive livestock production and grazing operations, and fertilizer use in the watershed.

Data Source

Elevation data were obtained by line digitizing successive contour lines from a 1:24,000 U.S.Geological Survey quadrangle map. The digital topographic data was manipulated using ARC/INFO to obtain a Triangulated Irregular Network (TIN) for the Lake Icaria watershed (Figure 22). The ARC/INFO LATTICEPOLY was used with the slope, aspect, and range options to create coverage of polygon slope, aspect, and elevation, respectively. These vector coverages were converted to the grid format using the ARC/INFO GRID module.

The aerial photography of land use within the watershed were used to identify the cropping practices, the chemical oxygen demand (COD) values, management factor (C), support practice factor (P), fertilization level, fertilization availability factor, and Manning roughness coefficient (Table 6). The digital soil information for the study watersheds were obtained from the SCS ISOIL database (Figure 23). Using the incorporated the land use/land cover data with look-up tables, the soil hydrologic group, soil texture, surface condition constant, and SCS curve number were derived (Table 7).

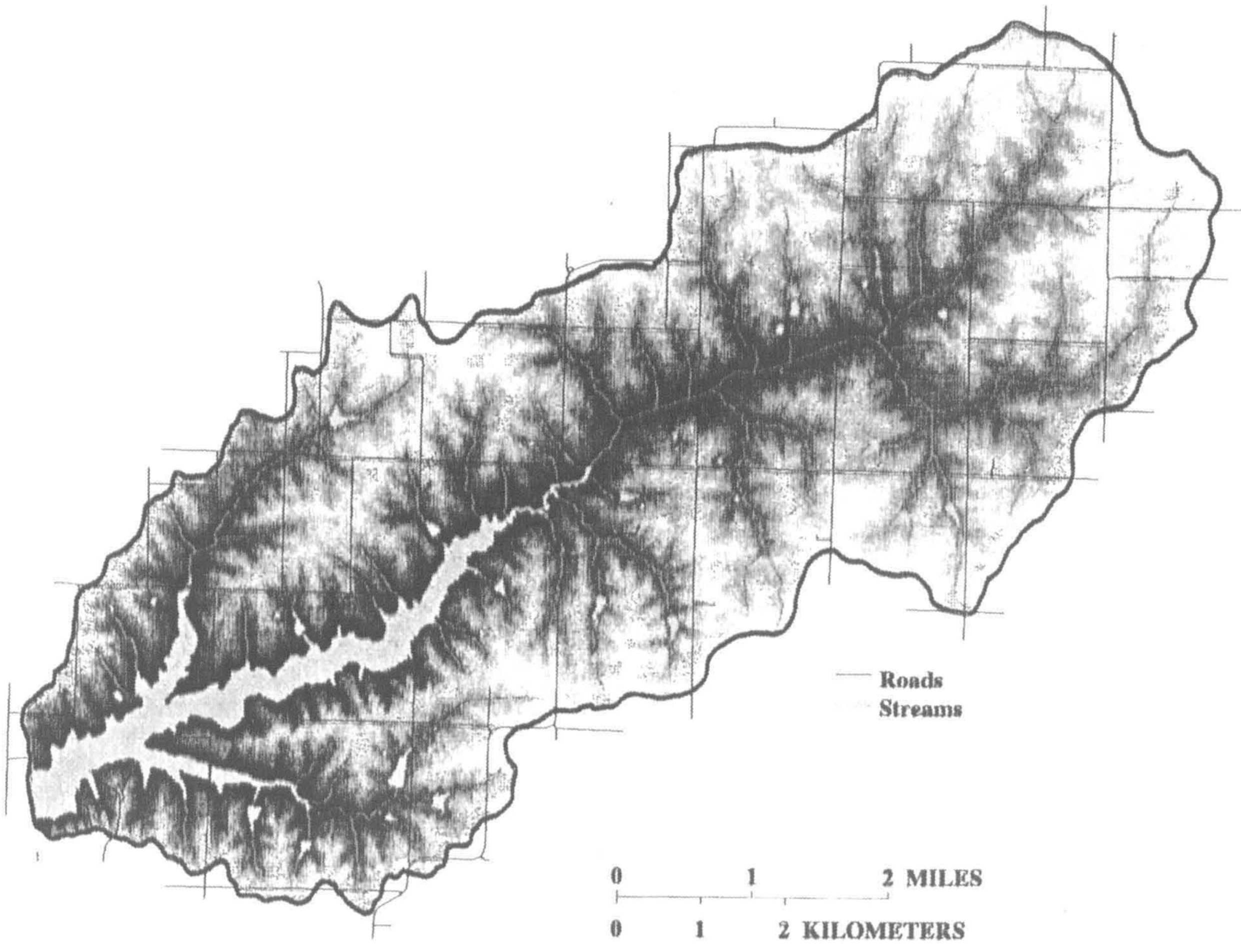


Figure 22. Lake Icaria Watershed : Topographic map

Table 6. Land use attribute table

Land Use Type	Manning Coefficient (n)	USLE Cover Factor (C)	USLE Practice Factor (P)	Fertilization Level [a] (FL)	Fertilizer Available (FA)	Surface Condition Constant (SCC)	Chemical Oxygen Demand (COD)
Corn	0.08	0.26	1	2	50	0.05	170
Soybeans	0.08	0.31	1	0	0	0.29	117
Hay	0.13	0.26	1	2	50	0.29	80
Pasture	0.25	0.01	1	1	85	0.29	20
Woodland	0.15	0.04	1	0	0	0.15	60
Hay (set aside)	0.35	0.01	1	0	0	0.00	65
Fallow	0.25	0.45	1	0	0	0.22	60
Water/Pond	0.99	0.00	0	1	0	0.00	0

[a] FL value of 2 = medium application of N,P, and K
FL value of 1 = high application of N,P, and K
FL value of 0 = no nutrient application

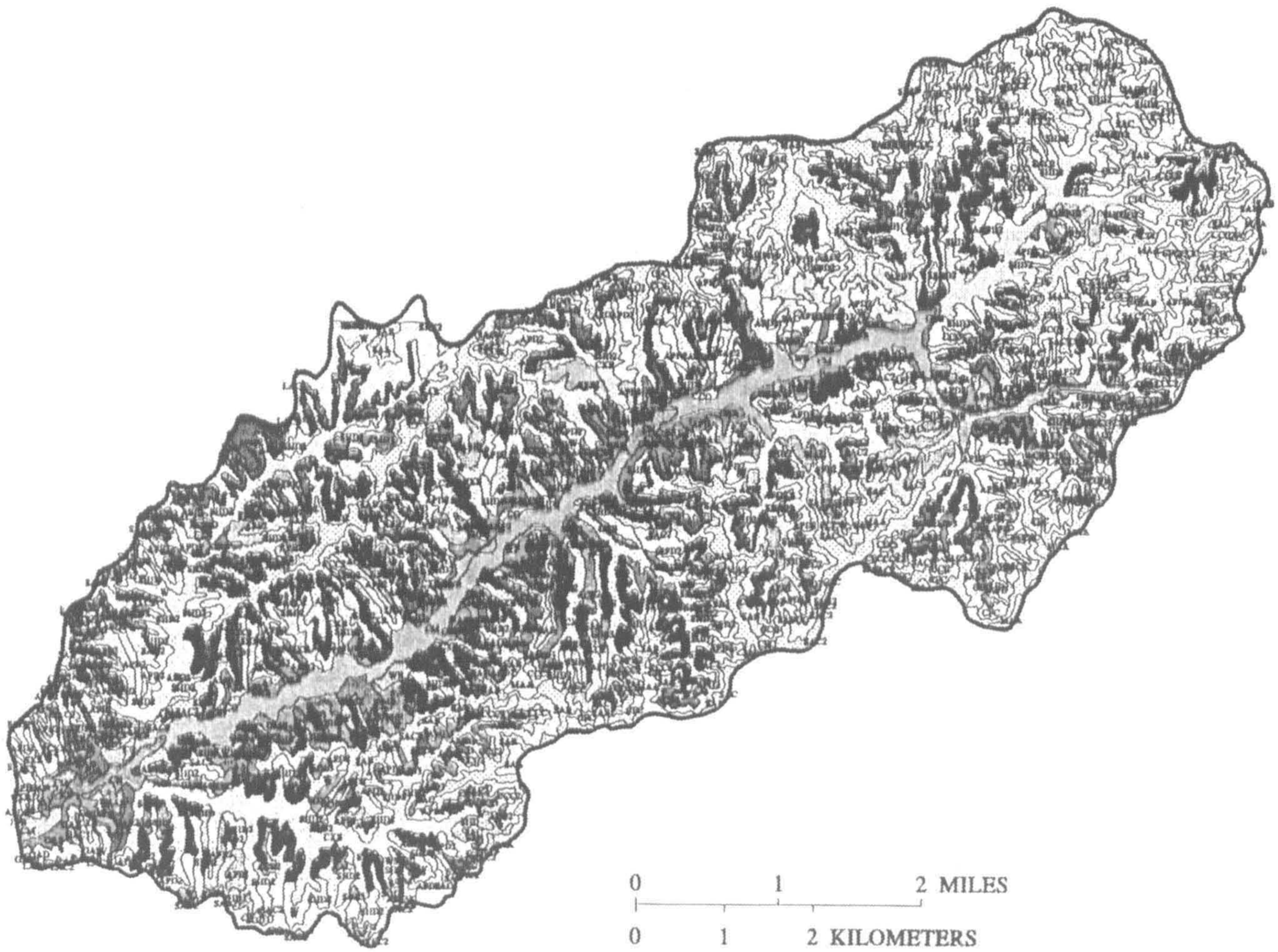


Figure 23. Lake Icaria Watershed : Soil map

Table 7. Land use look-up table for determining the SCS curve number

Land Use Type	SCS curve number for Soil Hydrologic Group			
	A	B	C	D
Corn	67	78	85	89
Soybeans	67	78	85	89
Small grain	63	74	82	85
Hay	58	72	81	85
Alfalfa	58	72	81	85
Oats	63	74	82	85
Pasture	39	61	74	80
Woodland	36	60	73	79
Hay (set aside)	58	72	81	85
Fallow	77	86	91	94
Water/Pond	100	100	100	100

Analysis

Topographic parameters, slope, aspect, and slope length; USLE (Universal Soil Loss Equation) parameters, soil erodibility (K), cropping factor (C), and practice factor (P); and hydrologic parameters, SCS curve number, manning coefficient, were managed and stored in ARC/INFO in both vector and raster formats, or with corresponding attribute data. The commands, POLYGRID, LINEGRID, and POINTGRID were used to generate grid file from the vector coverages. Using the GRIDASCII command, an ASCII text file can be generated.

Those parameters not generated in ARC/INFO were entered for entire watershed using the spatial purpose computer programs developed. After the execution of AGNPS, the GIS output file was organized by the interface to produce ARC/INFO ASCII text files which were converted to the grid format using ASCIIGRID. Furthermore, using the GRIDPOLY command, a vector coverage can be generated from the grid coverage and displayed in ARC/PLOT. The process was repeated for any output parameter of interest.

According to the AGNPS output, cell erosion, sediment yield, nitrogen loss and phosphorus loss were analyzed with the UNIVARIATE procedure in Statistical Analysis System (SAS Institute, Inc. 1985). The mean, median, minimum, maximum, upper and lower quartiles, and standard deviation were examined. The STEPWISE procedure was used to determine the dominant factors on the six dependent variables from 16 independent input variables (Table 8).

Table 8. Dependent and independent variables used in the STEPWISE procedure

Dependent variable	Independent variable	
Cell erosion (t/a)	Drainage area	Soil erodibility (K)
Sediment yield (tons/a)	Cell area	Cropping factor (C)
N loss in water (lbs/a)	Aspect	Surface condition constant
N loss concentration in water (ppm)	SCS curve number	Soil texture
	Slope	Fertilizer level
P loss in sediment (lbs/a)	Slope length	Fertilizer availability
P loss concentration in water ppm)	Mannings coefficient	Channel factor

RESULTS AND DISCUSSION

Statistical Analysis of Data

A UNIVARIATE statistical procedure was performed in order to analyze the results from the AGNPS model. The UNIVARIATE procedure can produce simple descriptive statistics for numeric variables as well as distribution of variables. Features include: (a) detail on the extreme values of a variable; (b) quartiles, such as the median; (c) several graphical plots to examine the distribution of a variable (stem-leaf plot, boxplot, and normal probability plot); and (d) frequency tables. Data can be separated for different groups of observations, and calculated for the descriptive statistics. The UNIVARIATE statistical procedure detailed in SAS (SAS, 1985) was adopted in this study.

In addition to the UNIVARIATE statistical procedure, the STEPWISE technique was used to analyze and identify the dominant factors from 16 independent water quality variables (e.g., soil erosion, sediment yield, nitrogen loss, and phosphorus loss). This procedure is useful when we have a collection of independent variables and wish to find which of the variables should be included in a regression model. The STEPWISE procedure provides five methods for stepwise regression: (a) forward selection; (b) backward selection; (c) stepwise; (d) maximum R^2 improvement; (e) minimum R^2 improvement. The stepwise procedure was chosen for data analysis. It is a modification of forward selection technique. In the forward selection method, variables are added one by one to the model, and the F-statistic for a variable to be added must be significant at the significant level (which the default is 0.15). After a variable is added, the stepwise method will look at all the variables already included in the model, and delete any variable that does not produce a significant level for F-statistic. Only after this check is made and the necessary deletions accomplished, can another variable be added to the model. The process terminates when no variable has F-statistic at the specified significance level.

Discussion of Simulation Results

During the simulation, the precipitation and rainfall intensity were assumed to be the same for the Lake Icaria watershed. Since the total area of the watershed is 7,071.88 hectare, the cell size was chosen to be 16 hectare to meet the AGNPS model limitation of 2500 cells. Table 9 summarizes the summary the watershed parameters used in the AGNPS model for the watershed.

The statistical output from the UNIVARIATE procedure are summarized in Table 10. Several statistical indicators including minimum, maximum, mean, median, lower and upper quartiles (Q1 and Q3) were used to reclassify output parameters, such as soil erosion, sediment yield, and nitrogen and phosphorus export rates (Table 11).

To analyze the simulation results for the two study watersheds, threshold values of water quality parameters were established. For soil erosion, a threshold value corresponding to soil tolerance factor (T) of 5 tons/acres/yr was established. Thus, any land cell with predicted soil erosion rates exceeding this value was classified as being potentially highly erodible. For the remaining water quality variables, the mean values

Table 9. Summary of AGNPS watershed parameters for Lake Icaria watershed

Watershed	Total area (hectare)	Cell size (hectare)	Total number of cell in watershed	Total area used in AGNPS simulation (hectare)
Lake Icaria	7,071.88	16	455	7,280

Table 10. Summary of the UNIVARIATE procedure for Lake Icaria watershed

Dependent variable	Min	Mean	Median	Max	Std. Dev.	Q1[a]	Q3[a]
Cell erosion (t/a)	0	31.12	1.05	2364.74	156.53	0.63	3.50
Sediment yield (t/a)	0	13.11	1.26	234.52	35.63	0.41	5.63
N loss in water (lbs/a)	0	0.83	0.60	3.66	0.64	0.39	1.43
N loss concentration in water (ppm)	0	0.43	0.05	2.00	0.53	0.03	0.80
P loss in sediment (lbs/a)	0	17.90	1.57	909.72	69.20	1.07	4.85
P loss concentration in water (ppm)	0	0.03	0.00	0.40	0.11	0.00	0.00

[a] Q1 = the first quartile, Q3 = the third quartile

Table 11. Reclassification of AGNPS simulation output for Lake Icaria watershed

Soil erosion (t/a)	%	Sediment yield (t/a)	%	N loss in water (lbs/a)	%	N loss concen. in water (ppm)	%	P loss in sediment (lbs/a)	%	P loss concen. in water (ppm)	%
0.0-5.0	65.05	0.00-0.41	40.22	0.00-0.39	25.71	0.00-1.00	86.81	0.00-1.07	32.74	0.00-1.00	97.80
5.0-10.0	5.49	0.41-1.26	14.07	0.39-0.60	37.14	1.00-2.00	9.89	1.07-1.57	4.84	1.00-2.00	2.20
10.0-15.0	4.62	1.26-5.63	15.60	0.60-0.83	17.14	2.00-3.00	2.20	1.57-4.85	22.20		
15.0-25.0	24.84	5.63-13.11	9.89	0.83-1.43	14.07	3.00-5.00	1.10	4.85-17.9	16.92		
		13.11-250	20.22	1.43-4.00	5.94			17.9-1000	23.30		

were used as thresholdvalues, since no threshold value exist in the literature.

As shown in Table 11, for the Lake Icaria watershed, over 65% of land area had soil erosion rate less than T. Total sediment yield in AGNPS is calculated by multiplying the sediment yield per acres by cell area. There is a significant difference in the critical source area of sediment pollution. Since the phosphorus loss is with the sediment, the amount of phosphorus loss will increase when the sediment yield increase. Therefore the Lake Icaria watershed has high sediment yield. For the concentration of phosphorus in water, both of them area within the threshold value which is 2 ppm.

Table 12 shows the summary of the STEPWISE procedure in examining the dominant factors for soil erosion rates, sediment yield, and nitrogen and phosphorus loss loadings. These water quality variables, which exhibit partial R^2 greater than or equal to 0.01, were selected to be the important factors. For cell erosion, land slope, cropping factor (C), and soil erodibility factor (K) were more important than other factors that influence soil erosion (e.g., structural practice factor, slope length factor, etc). As shown in Table 12, only 38% of the soil erosion process could be explained by these factors; thus there might be some other variables which were not included in the STEPWISE analysis that might influence soil erosion process, or some nonlinear relationship might exist in the model. In the analysis of results for sediment yield, the total drainage area, the total of soil erosion, land slope, soil erodibility (K), and channel indicator, were selected as the main factors. However these factors can only explain 21% of the sediment yield, which indicates more factors are needed. It is important to also note that sediment yield response is a nonlinear process and

Table 12. Summary of the STEPWISE procedure for cell soil erosion, sediment yield, and nitrogen, phosphorus losses.

Dependent	Independent	Partial R^2	Model R^2
Soil erosion (t/a)	Slope	0.33	0.33
	Cropping factor	0.04	0.37
	Soil erodibility	0.01	0.38
Sediment yield (t/a)	Slope	0.11	0.11
	Channel indicator	0.05	0.16
	Soil erodibility	0.03	0.19
	Drainage area	0.01	0.20
	Soil erosion	0.01	0.21
N loss in water (lbs/a)	Fertilizer level	0.67	0.67
	Curve number	0.12	0.79
	Soil texture	0.02	0.81
N loss concentration in water (ppm)	Slope length	0.79	0.79
	Fertilizer level	0.10	0.89
P loss in sediment (lbs/a)	Soil erosion	0.98	0.98
P loss concentration in water (ppm)	Fertilizer level	0.15	0.15
	Slope length	0.02	0.17
	Soil texture	0.10	0.27
	Channel factor	0.01	0.28

is predicted in AGNPS using the empirical relationship proposed by Bagnold (1966).

For nitrogen, the total amount exported in the water soluble phrase is highly related to the fertilizer level, curve number, soil texture, and fertilization level. Further, the differences in soil characteristics and anfeccedent soil moisture condition used in curve number technique can affect the amount of nitrogen in surface runoff. While for the nitrogen loss concentration in water soluble, the fertilizer level and slope length show the high influences and account for 89% of the losses. For the amounts of phosphorus exported with sediment, only the factors influencing soil erosion were selected by the STEPWISE procedure, and collectively they account for 98% of the phosphorus losses. Phosphorus export with water was influenced by the fertilization level, slope length, soil texture, and the channel indicator. As predicted by the STEPWISE, these factors are considered to dominate phosphorus concentrations in water by only 28%. Phosphorus is readily adsorbed to soil particles and its concentration in this phase is highly correlated with the clay mineral content of the soil.

The spatial distribution of soil erosion, sediment yield, and nitrogen and phosphorus exports are shown in Figure 24 through Figure 29 for both study watersheds. For the Lake Icaria watershed, the land areas with high soil erosion rates, sediment yield, and phosphorus loading (in sediment bound) are located adjacent to the water bodies (lake, stream). However, for the Dry Run watershed, the critical areas are situated at south-east corner of watershed boundary. For the nutrient (nitrogen and phosphorus) losses in water, most of the critical areas of the Dry Run watershed are located at upland areas with row crop production, while in the Lake Icaria watershed, the critical areas follow the main drainage pattern instead of land use.

Figure 24. Lake Icaria watershed : predicted soil erosion rates

Figure 25. Lake Icaria watershed : predicted sediment yield

Figure 26. Lake Icaria watershed : predicted nitrogen loss in water-soluble phrase

Figure 27. Lake Icaria watershed : simulated nitrogen loss concentration

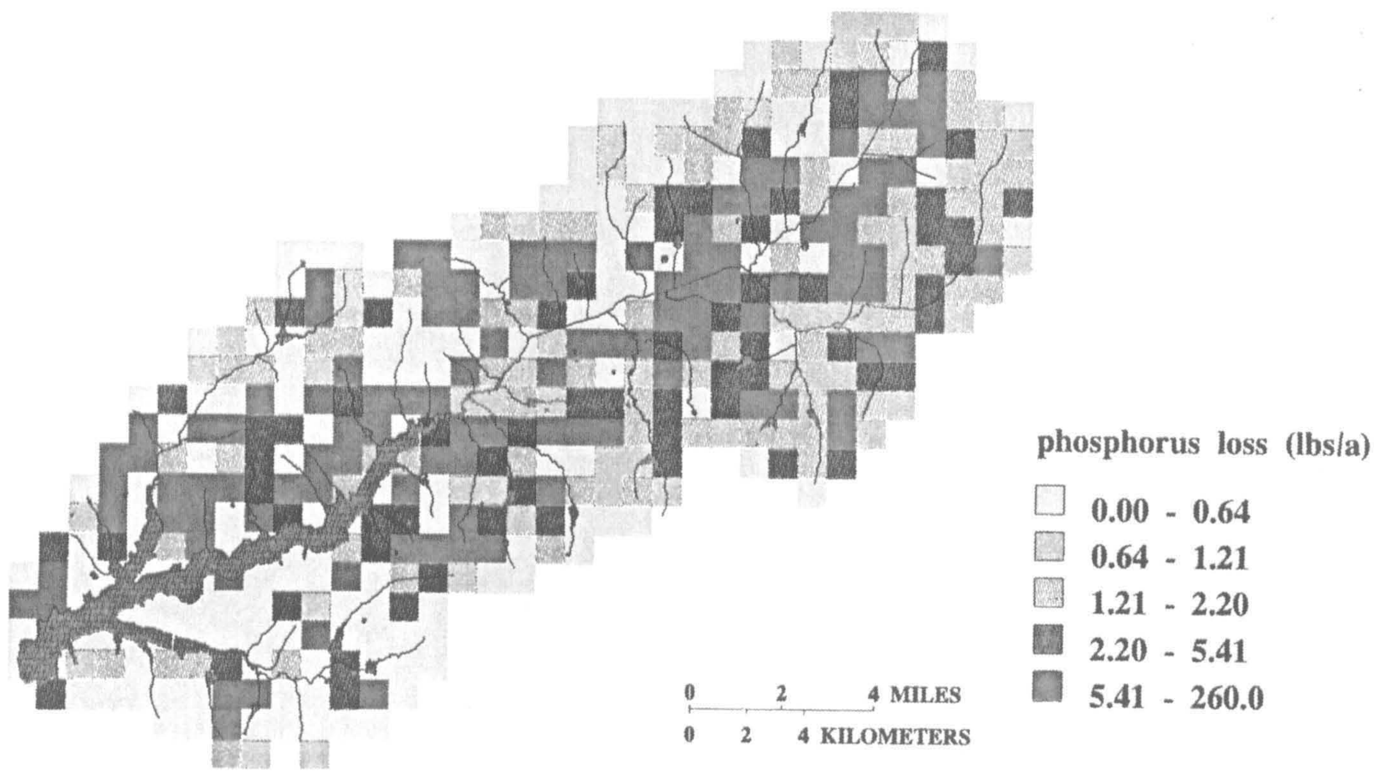


Figure 28. Lake Icaria watershed : predicted phosphorus export in sediment-bound phrase

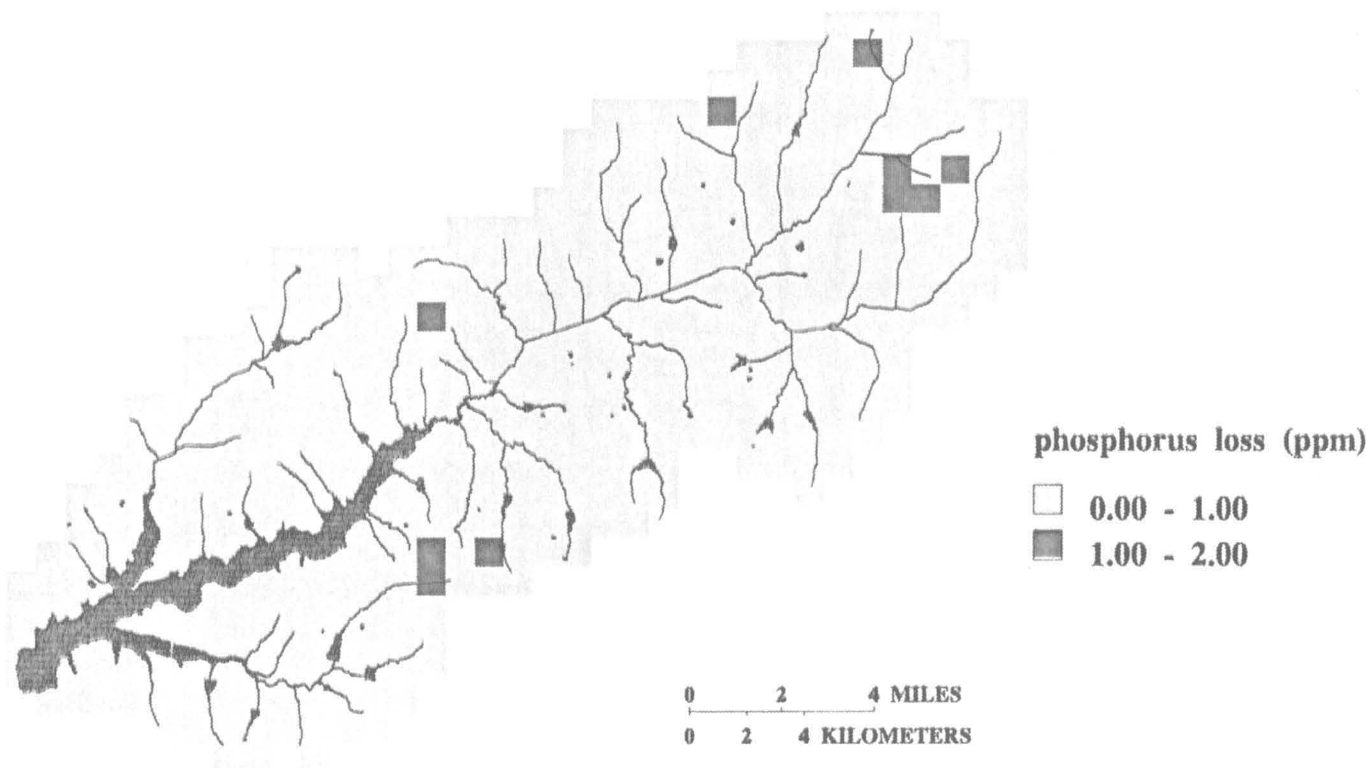


Figure 29. Lake Icaria watershed : predicted phosphorus losses in water-soluble phrase

SUMMARY AND CONCLUSION

GIS technology is improving the ability of scientist to utilize and manage large amounts spatially distributed data. In water quality modeling, the characteristics of data are always changing from location to location or from time to time. Therefore, collection, storage, and manipulation of large volumes of data can be an impediment in the implementation of water quality models. By using a GIS, large quantities of model input data can be manipulated very efficiently in time.

For managing pollution problems at a large scale, a framework to manipulate the large amounts of model input data is required. GIS can make significant contributions to in this application area by solidifying the treatment of spatial variations and manipulating spatial distributed data for model use. In doing so, detailed model can become more accurate and less costly to implement. Although, the inability to handle extensive amount of model parameters may limit the use of existing distributed parameter models, the integration with GIS can solve the problem.

The integration of GIS with water quality models is playing an important role in designing, modifying, and comparing the results of simulation. A further development of user interface is sometimes required in data transformation between GIS and models, and will make GIS a more practical bridge between environmental planner, decision maker, and the tools for making the necessary management decisions. Not only answering the "what-if" type of questions, GIS also provides valuable insight into tne spatial ramification of the proposed activity.

In this study, an interface program was developed to integrate AGNPS model with ARC/INFO GIS for manipulation, analysis and display of input/output parameter. The interface provides an efficient, less labor intensive, and cost-effective framework for identifying critical nonpoint pollution source areas of a watershed for resource allocation. Through two example applications involving watersheds of various size , the interface, which consisted of "special purpose" computer programs, has provided the capability for efficient management of spatial disparate model data. The model output represented by GIS can enhanced the impact in decision making process. In general, the interface and modeling framework presented in this study can provide natural resource planners an easy-to-use tool that integrates environmental modeling and GIS for decision-making.

Visualization and analysis of input and/or output data are important aspects of the decision-making process. In this study, a simple statistical analysis, UNIVARIATE procedure, was conducted to reclassify, compare, or analyze the predicted water quality parameters including soil erosion, sediment yield, and nitrogen and phosphorus loadings.

The STEPWISE statistical procedure was employed to identify the dominant factors from the output data for six dependent variables (soil erosion, sediment yield, and nitrogen and phosphorus losses). Slope was the important factor in determining soil erosion and sediment yield. The fertilization level had significant influence on nitrogen and phosphorus losses in water. Furthermore, the phosphorus loading in sediment was highly correlated with soil erosion.

FUTURE WORK

GISs are useful tools for solving spatial problems by manipulating large amounts of locational data from various sources. However, in water quality modeling, most of data required in models are spatial correlated, and require some analysis render then compatible with existing models. Therefore, spatial statistical analysis will become an important issue in handling the spatial relationship for environmental modeling.

On the other hand, the image data from remote sensors can also be used in an environmental modeling framework. For example, the image data can be obtained by using different wavelength, and the gray level will be different based on the characteristics of different objects. Therefore, some data can be derived by doing some combination, or algebra calculation on these image data. Overall, remotely sensed information can be incorporated into current environmental analysis and management.

The following items require additional research:

1. Develop protocols for integrating spatial statistics and remotely sensed data into existing GIS-based hydrology/water quality modeling systems.
2. Apply the protocols to simulate the nonpoint source pollution, such as soil erosion, sediment transport, and nutrient losses in surface and groundwater systems.
3. Develop simplified pollutant export models within the GIS environment for comparison with complex models such as AGNPS and ANSWERS.

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APPENDIX A:

PROGRAM OF INTERFACE -- PART I

FILE CONVERSION

```
program coding;

uses Crt;

label 10,20;

const
    outfile_ext='.trn';

type head=record
        set_ncols:string[14];
        ncol:integer;
        set_nrows:string[14];
        nrow:integer;
        set_x_min:string[14];
        x_min:real;
        set_y_min:string[14];
        y_min:real;
        set_size:string[14];
        cellsize:integer;
        set_nodata:string[14];
        nodata:integer;
          end;
var
    boundary,aspect:integer;
    trans:integer;
    cell_no,flowcell_no : integer;
    control_row,control_col:integer;
    in_file,out_file:string[20];
    in_name,out_name:string[20];
    cursor,count,control:longint;
    flow,check,direct_cell:integer;
    i,j,m,n : integer;
    bound:file of integer;
    code,river,flowcode,checkriver:file of integer;
    asp,overasp,checkasp:file of integer;


procedure input_boundary;  (*  input_boundary file  *)

var
    header:head;
    int:text;

begin
    ClrScr;
```

```
   gotoxy(10,4);

writeln('==============================================
=======');
   gotoxy(10,5);
   writeln('        Input the BOUNDARY file :                 ');
   gotoxy(10,6);

writeln('==============================================
=======');
   gotoxy(10,8);
   write('Enter the BOUNDARY text file : ');
   readln(in_file);
   in_name:=in_file;
   assign(int,in_name);
   reset(int);

   gotoxy(10,10);
   write('Enter the OUTPUT boundary file name [***.trn] : ');
   readln(out_file);
   out_name:=out_file+outfile_ext;
   assign(bound,out_name);
   rewrite(bound);

   with header do
   begin
     readln(int,set_ncols,ncol);
     readln(int,set_nrows,nrow);
     readln(int,set_x_min,x_min);
     readln(int,set_y_min,y_min);
     readln(int,set_size,cellsize);
     readln(int,set_nodata,nodata);
     gotoxy(10,12);
     writeln('X minimun is : ',x_min:15:3);
     gotoxy(10,13);
     writeln('Y minimun is : ',y_min:15:3);
     gotoxy(10,14);
     writeln('Cell size is : ',cellsize:10);
     gotoxy(10,15);
     writeln('# row : ',nrow:5,'    # column : ',ncol:5);
     gotoxy(10,16);
     writeln('No data value is : ',nodata:10);
   end;

   repeat
     gotoxy(10,18);
     writeln('Hit space bar to continue .....');
```

```
    until keypressed;

    m:=header.nrow;
    n:=header.ncol;
    for i:=1 to m do
      for j:=1 to n do
         begin
           read(int,boundary);
         if boundary=-9999 then
           begin boundary:=0;
                 write(bound,boundary);
           end
          else write(bound,boundary);
         end;

    close(int);
    close(bound);

end;   (* end of input boundary file *)


procedure translate;     (*  translate file  *)

label 100;

type head=record

         set_ncols:string[14];
         ncol:integer;
         set_nrows:string[14];
         nrow:integer;
         set_x_min:string[14];
         x_min:real;
         set_y_min:string[14];
         y_min:real;
         set_size:string[14];
         cellsize:integer;
         set_nodata:string[14];
         nodata:integer;
           end;

var
     header:head;
     trans_real:real;
     k:integer;
     int:text;
     out1:file of integer;
```

```
    out2:file of real;

begin
    reset(bound);

    ClrScr;
    gotoxy(10,4);
writeln('==================================================
=======');
    gotoxy(10,5); writeln('            TRANSLATE  file  :                ');
    gotoxy(10,6);
writeln('==================================================
=======');
    gotoxy(10,7); writeln('<1>  SCS curve number ');
    gotoxy(10,8); writeln('<2>  Average land slope % ');
    gotoxy(10,9); writeln('<3>  Slope shape factor ');
    gotoxy(10,10);writeln('<4>  Average slope length ');
    gotoxy(10,11);writeln('<5>  Mannings roughness coeff.');
    gotoxy(10,12);writeln('<6>  K factor from USLE ');
    gotoxy(10,13);writeln('<7>  C factor from USLE ');
    gotoxy(10,14);writeln('<8>  P factor from USLE ');
    gotoxy(10,15);writeln('<9>  Surface condition const.');
    gotoxy(10,16);writeln('<10> Aspect ');
    gotoxy(42,7); writeln('<11> Soil texture ');
    gotoxy(42,8); writeln('<12> Fertilization level ');
    gotoxy(42,9); writeln('<13> Incorporation factor % ');
    gotoxy(42,10);writeln('<14> Point source indicator ');
    gotoxy(42,11);writeln('<15> Gully source level ');
    gotoxy(42,12);writeln('<16> Chemical oxygen demand');
    gotoxy(42,13);writeln('<17> Impoundment factor ');
    gotoxy(42,14);writeln('<18> Channel indicator');
    gotoxy(42,15);writeln('<19> Flow direction');
    gotoxy(10,17);writeln('<88> Other file <integer format>');
    gotoxy(10,18);writeln('<99> Other file <real format>');
    gotoxy(10,19);writeln(' 0==> Quit ');

gotoxy(10,20);writeln('========================================
=============');
    gotoxy(10,22);
    write('Please enter the selection : ');
    readln(k);
    if k=0 then goto 100;

    ClrScr;

gotoxy(10,4);writeln('========================================
=============');
```

```
gotoxy(10,5);
case k of
1: writeln('   Convert  SCS CURVE NUMBER <CN>  ');
2: writeln('   Convert  SLOPE ');
3: writeln('   Convert  SLOPE SHAPE ');
4: writeln('   Convert  SLOPE LENGTH ');
5: writeln('   Convert  MANNING ROUGHNESS COEFF.');
6: writeln('   Convert  K FACTOR ');
7: writeln('   Convert  C FACTOR ');
8: writeln('   Convert  P FACTOR ');
9: writeln('   Convert  SURFACE CONDITION CONST. <SCC>');
10:writeln('   Convert  ASPECT ');
11:writeln('   Convert  SOIL TEXTURE ');
12:writeln('   Convert  FERTILIZER LEVER <FL>');
13:writeln('   Convert  FERTILIZER INCOROPORATION <FA>');
14:writeln('   Convert  POINT SOURCE ');
15:writeln('   Convert  GULLY SOURCE ');
16:writeln('   Convert  CHEMICAL OXYGEN DEMAND <COD>');
17:writeln('   Convert  IMPOUNDMENT FACTOR');
18:writeln('   Convert  CHANNEL INDICATOR ');
19:writeln('   Convert  FLOW DIRECTION');
88:writeln('   Convert  other INTEGER FORMAT file ');
99:writeln('   Convert  other REAL FORMAT file');
end;


gotoxy(10,6);writeln('====================================
=============');

gotoxy(10,8);
write('Please enter the file name : ');
readln(in_file);
in_name:=in_file;
assign(int,in_name);
reset(int);

gotoxy(10,10);
write('Please give the OUTPUT file name [***.trn] : ');
readln(out_file);
out_name:=out_file+outfile_ext;
if k in [2,5,6,7,8,9,99] then
  begin
    assign(out2,out_name);
    rewrite(out2)
  end
 else
  begin
```

```
    assign(out1,out_name);
    rewrite(out1);
  end;


with header do
begin
  readln(int,set_ncols,ncol);
  readln(int,set_nrows,nrow);
  readln(int,set_x_min,x_min);
  readln(int,set_y_min,y_min);
  readln(int,set_size,cellsize);
  readln(int,set_nodata,nodata);
  gotoxy(10,12); writeln('X minimun is : ',x_min:15:3);
  gotoxy(10,13); writeln('Y minimun is : ',y_min:15:3);
  gotoxy(10,14); writeln('Cell size is : ',cellsize:10);
  gotoxy(10,15); writeln('# Row : ',nrow:5,'  # Columns : ',ncol:5);
  gotoxy(10,16); writeln('No data value is : ',nodata:10);
end;

repeat
  gotoxy(10,18);
  writeln('Hit space bar to continue .....');
until keypressed;

m:=header.nrow;
n:=header.ncol;
for i:=1 to m do
  for j:=1 to n do
      begin
      if k in [2,5,6,7,8,9,99] then
         begin
           read(int,trans_real);
           if k=3 then begin case trunc(trans_real) of
                            1: trans_real:=0.5;
                            2: trans_real:=1.6;
                            3: trans_real:=3.4;
                            4: trans_real:=7.32;
                            5: trans_real:=15.75;
                            6: trans_real:=33.95;
                            7: trans_real:=60.00;
                            8: trans_real:=100;
                        -9999: trans_real:=0.00;
                            end;
                      end;
           if trans_real=-9999 then trans_real:=0.00;
         end
```

```
        else
         begin
           read(int,trans);
           if trans=-9999 then trans:=0;
         end;

        cursor:=(i-1)*n+j-1;
        seek(bound,0);
        seek(bound,cursor);
        read(bound,boundary);
        if boundary<>0 then
          if k in [2,5,6,7,8,9,99] then write(out2,trans_real)
            else write(out1,trans)
        else if k in [2,5,6,7,8,9,99] then
                 begin
                   trans_real:=0.00;
                   write(out2,trans_real)
                 end
               else write(out1,boundary);
      end;

    close(int);
    if k in [2,5,6,7,8,9,99] then close(out2)
      else close(out1);

    close(bound);

100:end;   (* end of procedure translate *)


procedure codeing;  (*  start coding each cell from upleft to lowright  *)
var
    cell_no:integer;

begin
    reset(bound);
    ClrScr;

gotoxy(10,4);writeln('====================================
==============');
    gotoxy(10,5);writeln('            CODING each cell :                  ');

gotoxy(10,6);writeln('====================================
==============');
    gotoxy(10,8);write('Name the output CODING file [***.trn] : ');
    readln(out_file);
    out_name:=out_file+outfile_ext;
```

```
    assign(code,out_name);
    rewrite(code);


    cell_no:=0;
    for i:= 1 to m do
      for j:=1 to n do
          begin
            cursor:=(i-1)*n+j-1;
            seek(bound,0);
            seek(bound,cursor);
            read(bound,boundary);
            if boundary=0 then
              write(code,boundary)
             else
               begin
                   cell_no:=cell_no+1;
                   write(code,cell_no);
               end;
          end;

    close(code);

end;                        (* end of procedure coding  *)

procedure check_flow_and_aspect_direction;  (* search control point and check aspect *)

label 30,35,40,50,60,65,70,80,90;

var
    find_control,opposit:integer;
    search_cursor:longint;
    check,check_flow,search:integer;
    diff:integer;

begin
    reset(bound);reset(code);
    ClrScr;

gotoxy(10,4);writeln('=======================================
==============');
    gotoxy(10,5);writeln('        SEARCH the control point :              ');

gotoxy(10,6);writeln('=======================================
==============');
    gotoxy(10,8);write('     Enter the FLOW_DIRECTION file <***.trn> : ');
    readln(in_file);
```

```
in_name:=in_file+outfile_ext;
assign(river,in_name);
reset(river);

for i:=1 to m do
  for j:=1 to n do
    begin
      cursor:=(i-1)*n+j-1;
      seek(bound,0);
      seek(bound,cursor);
      read(bound,boundary);
      if boundary<>0 then
        begin
          seek(river,0);
          seek(river,cursor);
          read(river,flow);

        seek(code,0);
        seek(code,cursor);
        read(code,cell_no);

        if (i=1) and (flow in [8,1,2]) then goto 35;
        if (i=m) and (flow in [4,5,6]) then goto 35;
        if (j=1) and (flow in [6,7,8]) then goto 35;
        if (j=n) and (flow in [2,3,4]) then goto 35;

          case flow of
            0:count:=0;
            1:count:=((i-1)-1)*n+j-1;
            2:count:=((i-1)-1)*n+(j+1)-1;
            3:count:=(i-1)*n+(j+1)-1;
            4:count:=((i+1)-1)*n+(j+1)-1;
            5:count:=((i+1)-1)*n+j-1;
            6:count:=((i+1)-1)*n+(j-1)-1;
            7:count:=(i-1)*n+(j-1)-1;
            8:count:=((i-1)-1)*n+(j-1)-1;
          end;

          if count=0 then goto 30;
        if count>m*n then
          if cell_no=0 then goto 30
            else
             goto 35;

          seek(bound,0);
          seek(bound,count);
          read(bound,boundary);
```

```
          if boundary=0 then
               if cell_no=0 then goto 30
              else
               goto 35;

        35:gotoxy(10,10); writeln('cursor is ',i:4,j:4);
          gotoxy(10,11); writeln('Outlet cell # : ',cell_no:6);

          end;

    30:end;

   gotoxy(10,15); write('Please enter the correct OUTPUT cell no. : ');
   readln(control);
   ClrScr;

gotoxy(10,4);writeln('==================================
==============');
   gotoxy(10,5);writeln('        CHECK the flow direction :              ');

gotoxy(10,6);writeln('==================================
==============');
   gotoxy(10,8);write('     Name for river direction checking [***.trn] : ');
   readln(in_file);
   in_name:=in_file+outfile_ext;
   assign(checkriver,in_name);
   rewrite(checkriver);


   for i:=1 to m do
    for j:=1 to n do
        begin
          cursor:=(i-1)*n+j-1;
          seek(code,0);
          seek(code,cursor);
          read(code,find_control);
          if find_control=control then
            begin
              control_row:=i;
              control_col:=j;
              goto 50;
            end;
        end;

50:     gotoxy(10,10);writeln('Control point at ',control_row:3,control_col:4);

    for i:=1 to m do
```

```
for j:=1 to n do
   begin
     cursor:=(i-1)*n+j-1;
     seek(river,0);
     seek(river,cursor);
     read(river,flow);
     if (i=control_row) AND (j=control_col) then
       begin
         write(checkriver,flow);
         goto 40;
       end;
     case flow of
      0:count:=0;
      1:count:=((i-1)-1)*n+j-1;
      2:count:=((i-1)-1)*n+(j+1)-1;
      3:count:=(i-1)*n+(j+1)-1;
      4:count:=((i+1)-1)*n+(j+1)-1;
      5:count:=((i+1)-1)*n+j-1;
      6:count:=((i+1)-1)*n+(j-1)-1;
      7:count:=(i-1)*n+(j-1)-1;
      8:count:=((i-1)-1)*n+(j-1)-1
     end;
     if count=0 then
       begin
         write(checkriver,flow);
         goto 40
       end;
     seek(river,0);
     seek(river,count);
     read(river,check);

    if (i=1) and (flow in [8,1,2]) then goto 65;
    if (i=m) and (flow in [4,5,6]) then goto 65;
    if (j=1) and (flow in [6,7,8]) then goto 65;
    if (j=n) and (flow in [2,3,4]) then goto 65;

      if check=0 then
        begin
       65:check_flow:=flow;
    60: diff:=check_flow-flow;
         case diff of
           0 : check_flow:=flow-1;
           -1: check_flow:=flow+1;
           +1: check_flow:=flow-2;
           -2: check_flow:=flow+2;
           +2: check_flow:=flow-3;
           -3: check_flow:=flow+3;
```

```
          +3: check_flow:=flow-4;
         end;
        if check_flow=0 then check_flow:=8;
        if check_flow>8 then check_flow:=check_flow-8;
          case check_flow of
            1:search_cursor:=((i-1)-1)*n+j-1;
            2:search_cursor:=((i-1)-1)*n+(j+1)-1;
            3:search_cursor:=(i-1)*n+(j+1)-1;
            4:search_cursor:=((i+1)-1)*n+(j+1)-1;
            5:search_cursor:=((i+1)-1)*n+j-1;
            6:search_cursor:=((i+1)-1)*n+(j-1)-1;
            7:search_cursor:=(i-1)*n+(j-1)-1;
            8:search_cursor:=((i-1)-1)*n+(j-1)-1
          end;
          seek(river,0);
          seek(river,search_cursor);
          read(river,search);
        if search=0 then goto 60;
          write(checkriver,check_flow);
        end
      else
        write(checkriver,flow);
  40:end;

  ClrScr;

gotoxy(10,4);writeln('==================================================
==============');
  gotoxy(10,5);writeln('    Overlay the FLOW and ASPECT files :      ');
  gotoxy(10,6);writeln('================================================================
  gotoxy(10,8);write(' Enter the source ASPECT file <***.trn> : ');
  readln(in_file);
  in_name:=in_file+outfile_ext;
  assign(asp,in_name);
  reset(asp);

  gotoxy(10,10);write(' Name the output OVERLAY ASPECT file <***.trn> : ');
  readln(out_file);
  out_name:=out_file+outfile_ext;
  assign(overasp,out_name);
  rewrite(overasp);

  reset(bound);
  for i:=1 to m do
    for j:=1 to n do
      begin
        cursor:=(i-1)*n+j-1;
```

```
        read(bound,boundary);
        if boundary< >0 then
          begin
            seek(checkriver,0);
            seek(checkriver,cursor);
            read(checkriver,flow);
            if flow=0 then
                begin
                  seek(asp,0);
                  seek(asp,cursor);
                  read(asp,flow);
                  write(overasp,flow);
                end
               else
                write(overasp,flow);
          end
         else
          write(overasp,boundary);
      end;

  ClrScr;

gotoxy(10,4);writeln('======================================
=============');
  gotoxy(10,5);writeln('            Check the ASPECT :               ');

gotoxy(10,6);writeln('======================================
=============');
  gotoxy(10,8);write('  Name the ASPECT checking file [***.trn] : ');
  readln(in_file);
  in_name:=in_file+outfile_ext;
  assign(checkasp,in_name);
  rewrite(checkasp);

  for i:=1 to m do
    for j:=1 to n do
      begin
        cursor:=(i-1)*n+j-1;
        seek(bound,0);
        seek(bound,cursor);
        read(bound,boundary);
        if boundary< >0 then
          begin
            seek(overasp,0);
            seek(overasp,cursor);
            read(overasp,flow);
            if (i=control_row) AND (j=control_col) then
```

```
      begin
        write(checkasp,flow);
        goto 80;
      end;
  case flow of
 0:goto 90;
     1:count:=((i-1)-1)*n+j-1;
     2:count:=((i-1)-1)*n+(j+1)-1;
     3:count:=(i-1)*n+(j+1)-1;
     4:count:=((i+1)-1)*n+(j+1)-1;
     5:count:=((i+1)-1)*n+j-1;
     6:count:=((i+1)-1)*n+(j-1)-1;
     7:count:=(i-1)*n+(j-1)-1;
     8:count:=((i-1)-1)*n+(j-1)-1
  end;

 if count>m*n then goto 90;

 if (i=1) and (flow in [8,1,2]) then
  begin
    count:=0; goto 90;
  end;
 if (i=m) and (flow in [4,5,6]) then
  begin
    count:=0; goto 90;
  end;
 if (j=1) and (flow in [6,7,8]) then
  begin
    count:=0; goto 90;
  end;
 if (j=n) and (flow in [2,3,4]) then
  begin
    count:=0; goto 90;
  end;

  seek(bound,0);
  seek(bound,count);
  read(bound,check);

90:if (check=0) or (flow=0) or (count=0) then
      begin
    if flow=0 then flow:=8;
    check_flow:=flow;

  70:diff:=check_flow-flow;
    if abs(check_flow-flow)>3 then
      if diff<0 then
```

```
    begin
      check_flow:=check_flow+8;
      diff:=check_flow-flow;
    end
   else if check_flow>=8 then
          begin
            check_flow:=check_flow-8;
            diff:=check_flow-flow;
          end;

case diff of
 0: check_flow:=flow-1;
-1: check_flow:=flow+1;
 1: check_flow:=flow-2;
-2: check_flow:=flow+2;
 2: check_flow:=flow-3;
-3: check_flow:=flow+3;
 3: check_flow:=flow-4;
end;

if check_flow<=0 then check_flow:=check_flow+8;
if check_flow>8  then check_flow:=check_flow-8;

case check_flow of
      1:search_cursor:=((i-1)-1)*n+j-1;
      2:search_cursor:=((i-1)-1)*n+(j+1)-1;
      3:search_cursor:=(i-1)*n+(j+1)-1;
      4:search_cursor:=((i+1)-1)*n+(j+1)-1;
      5:search_cursor:=((i+1)-1)*n+j-1;
      6:search_cursor:=((i+1)-1)*n+(j-1)-1;
      7:search_cursor:=(i-1)*n+(j-1)-1;
      8:search_cursor:=((i-1)-1)*n+(j-1)-1
    end;

if search_cursor<0 then goto 70;
if (i=1) and (check_flow in [8,1,2]) then goto 70;
if (i=m) and (check_flow in [4,5,6]) then goto 70;
if (j=1) and (check_flow in [6,7,8]) then goto 70;
if (j=n) and (check_flow in [2,3,4]) then goto 70;

seek(bound,0);
seek(bound,search_cursor);
read(bound,boundary);
if boundary=0 then goto 70;


    seek(overasp,0);
```

```
        seek(overasp,search_cursor);
        read(overasp,search);
      if search=0 then goto 70;
        write(checkasp,check_flow);
      end
    else
      begin
        seek(overasp,0);
        seek(overasp,count);
        read(overasp,opposit);
        if Abs(flow-opposit)=4 then
          begin
            if flow in [1,2,7,8] then
              begin
                flow:=flow-1;
                if flow=0 then flow:=8;
                case flow of
                 1:count:=((i-1)-1)*n+j-1;
                 2:count:=((i-1)-1)*n+(j+1)-1;
                 3:count:=(i-1)*n+(j+1)-1;
                 4:count:=((i+1)-1)*n+(j+1)-1;
                 5:count:=((i+1)-1)*n+j-1;
                 6:count:=((i+1)-1)*n+(j-1)-1;
                 7:count:=(i-1)*n+(j-1)-1;
                 8:count:=((i-1)-1)*n+(j-1)-1
                end;
                seek(overasp,0);
                seek(overasp,count);
                read(overasp,opposit);
                if Abs(flow-opposit)=4 then
                  begin
                    flow:=flow+2;
                    if flow>8 then flow:=flow-8;
                    write(checkasp,flow);
                  end
                 else
                  write(checkasp,flow);
              end
            else
              write(checkasp,flow);
          end
         else
          write(checkasp,flow);
          goto 80
       end
  end
else
```

```
      write(checkasp,boundary);
   80:end;

  close(bound); close(river);  close(code);
  close(asp);   close(overasp); close(checkasp);  close(checkriver);

end;                    (* end of search and check *)

procedure calculate_receiving_cell;

label 100;

var
   int1,int2,int3,out1 : file  of integer;

begin
   reset(bound); reset(checkasp); reset(code);
   ClrScr;

gotoxy(10,4);writeln('==================================
==============');
   gotoxy(10,5);writeln('      Calculate Receiving Cell              ');

gotoxy(10,6);writeln('==================================
==============');
   gotoxy(10,8);write('  Name the Receiving cell file <***.trn> : ');
   readln(out_file);
   out_name:=out_file+outfile_ext;
   assign(flowcode,out_name);
   rewrite(flowcode);

   for i:=1 to m do
     for j:=1 to n do
        begin
        cursor:=(i-1)*n+j-1;
        if (i=control_row) and (j=control_col) then
          begin
            flowcell_no:=9999;
            write(flowcode,flowcell_no);
            goto 100;
          end;
          seek(bound,0);
          seek(bound,cursor);
          read(bound,boundary);
          if boundary<>0 then
            begin
              seek(checkasp,0);
```

```
            seek(checkasp,cursor);
            read(checkasp,aspect);
            case aspect of
              1:count:=((i-1)-1)*n+j-1;
              2:count:=((i-1)-1)*n+(j+1)-1;
              3:count:=(i-1)*n+(j+1)-1;
              4:count:=((i+1)-1)*n+(j+1)-1;
              5:count:=((i+1)-1)*n+j-1;
              6:count:=((i+1)-1)*n+(j-1)-1;
              7:count:=(i-1)*n+(j-1)-1;
              8:count:=((i-1)-1)*n+(j-1)-1
            end;
            seek(code,0);
            seek(code,count);
            read(code,flowcell_no);
            write(flowcode,flowcell_no);
          end
        else
          write(flowcode,boundary);
    100:end;

    close(flowcode);

end;

procedure write_text_file;

label 200;

var
    title:string[100];
    element:integer;
    k:integer;
    element_real:real;
    int1:file of integer;
    int2:file of real;
    out : text;

begin
    ClrScr;

gotoxy(10,4);writeln('==============================================
=============');
    gotoxy(10,5);writeln('        output the TEXT file   :                  ');

gotoxy(10,6);writeln('==============================================
=============');
```

```
    gotoxy(10,7); writeln('<1>  SCS curve number ');
    gotoxy(10,8); writeln('<2>  Average land slope % ');
    gotoxy(10,9); writeln('<3>  Slope shape factor ');
    gotoxy(10,10);writeln('<4>  Average slope length ');
    gotoxy(10,11);writeln('<5>  Mannings roughness coeff.');
    gotoxy(10,12);writeln('<6>  K factor from USLE ');
    gotoxy(10,13);writeln('<7>  C factor from USLE ');
    gotoxy(10,14);writeln('<8>  P factor from USLE ');
    gotoxy(10,15);writeln('<9>  Surface condition const.');
    gotoxy(10,16);writeln('<10> Aspect ');
    gotoxy(42,7); writeln('<11> Soil texture ');
    gotoxy(42,8); writeln('<12> Fertilization level ');
    gotoxy(42,9); writeln('<13> Incorporation factor % ');
    gotoxy(42,10);writeln('<14> Point source indicator ');
    gotoxy(42,11);writeln('<15> Gully source level ');
    gotoxy(42,12);writeln('<16> Chemical oxygen demand');
    gotoxy(42,13);writeln('<17> Impoundment factor ');
    gotoxy(42,14);writeln('<18> Channel indicator');
    gotoxy(42,15);writeln('<19> Flow direction');
    gotoxy(10,17);writeln('<88> Other file <integer format>');
    gotoxy(10,18);writeln('<99> Other file <real format>');
    gotoxy(10,19);writeln(' 0==> Quit ');

gotoxy(10,20);writeln('====================================
=============');
    gotoxy(10,22);
    write('Please enter the selection : ');
    readln(k);
    if k=0 then goto 200;

    ClrScr;

gotoxy(10,4);writeln('====================================
=============');
    gotoxy(10,5);
    case k of
    1: writeln('   Text Output :  SCS CURVE NUMBER <CN> ');
    2: writeln('   Text Output :  SLOPE ');
    3: writeln('   Text Output :  SLOPE SHAPE ');
    4: writeln('   Text Output :  SLOPE LENGTH ');
    5: writeln('   Text Output :  MANNING ROUGHNESS COEFF.');
    6: writeln('   Text Output :  K FACTOR ');
    7: writeln('   Text Output :  C FACTOR ');
    8: writeln('   Text Output :  P FACTOR ');
    9: writeln('   Text Output :  SURFACE CONDITION CONST. <SCC>');
    10:writeln('   Text Output :  ASPECT ');
    11:writeln('   Text Output :  SOIL TEXTURE ');
```

```
12:writeln('    Text Output :  FERTILIZER LEVER  <FL>');
13:writeln('    Text Output :  FERTILIZER INCOROPORATION  <FA>');
14:writeln('    Text Output :  POINT SOURCE ');
15:writeln('    Text Output :  GULLY SOURCE ');
16:writeln('    Text Output :  CHEMICAL OXYGEN DEMAND  <COD>');
17:writeln('    Text Output :  IMPOUNDMENT FACTOR');
18:writeln('    Text Output :  CHANNEL INDICATOR ');
19:writeln('    Text Output :  FLOW DIRECTION');
88:writeln('    Text Output :  other INTEGER FORMAT file ');
99:writeln('    Text Output :  other REAL FORMAT file');
end;


gotoxy(10,6);writeln('====================================
============');

    gotoxy(10,8);
    write('Please enter the file name [***.trn]: ');
    readln(in_file);
    in_name:=in_file+outfile_ext;

    if k in [2,5,6,7,8,9,99] then
      begin
        assign(int2,in_name);
        reset(int2)
      end
     else
      begin
        assign(int1,in_name);
        reset(int1);
      end;


    gotoxy(10,10);write('  Name the output TEXT file [***.dat] : ');
    readln(out_file);
    out_name:=out_file+'.dat';
    assign(out,out_name);
    rewrite(out);

    gotoxy(10,12);write('Title of the TEXT file : ');
    readln(title);
    writeln(out,title);

    for i:=1 to m do
      begin
         for j:=1 to n do
           begin
```

```
          if k in [2,5,6,7,8,9,99] then
            begin
              read(int2.element_real);
              write(out.element_real:4:1)
            end
           else
             begin
                read(int1,element);
              write(out,element:4);
             end
          end;
        writeln(out);
      end;

    if k in [2,5,6,7,8,9,99] then close (int2)
      else close(int1);
    close(out);

200:end;

procedure write_ascii_format;

label 300;

const nodata_value=-9999;

var
      header:head;
      k:byte;
      arc_integer:integer;
      arc_real:real;
      int1:file of integer;
      int2:file of real;
      out:text;

begin
     ClrScr;

gotoxy(10,4);writeln('======================================
==============');
     gotoxy(10,5);writeln('     Output the ARC/INFO ASCII text file          ');

gotoxy(10,6);writeln('======================================
==============');
     gotoxy(10,8);writeln('     1==> Transform a file of integer ');
     gotoxy(10,9);writeln('     2==> Transform a file of real ');
     gotoxy(10,10);writeln('     0==> quit ');
```

```
gotoxy(10,12);write('Please enter the selection : ');
readln(k);

if k=0 then goto 300;
gotoxy(10,14);write('Please enter the file name [***.trn] : ');
readln(in_file);
in_name:=in_file+outfile_ext;

if k=1 then
  begin
    assign (int1,in_name);
    reset(int1);
  end;
if k=2 then
  begin
    assign (int2,in_name);
    reset(int2);
  end;

gotoxy(10,16);write('   Name the output file [***.dat] : ');
readln(in_file);
in_name:=in_file+'.dat';
assign(out,in_name);
rewrite(out);

with header do
  begin
    writeln(out,set_ncols,ncol);
    writeln(out,set_nrows,nrow);
    writeln(out,set_x_min,x_min);
    writeln(out,set_y_min,y_min);
    writeln(out,set_size,cellsize);
    writeln(out,set_nodata,nodata);
  end;

gotoxy(10,18);write('Please enter the Boundary file name [***.trn] : ');
readln(in_file);
in_name:=in_file+outfile_ext;
assign(bound,in_name);
reset(bound);

gotoxy(10,20);write('Please enter #_row, #_column : ');
readln(m,n);

cursor:=0;

for i:=1 to m do
```

```
    begin
     for j:=1 to n do
       begin
         cursor:=(i-1)*n+j-1;
         seek(bound,0);
         seek(bound,cursor);
         read(bound,boundary);
         if boundary=0 then writeln(out,nodata_value:6);
         if boundary<>0 then
            case k of
            1:begin seek(int1,0);
                    seek(int1,cursor);
                    read(int1,arc_integer);
                    write(out,arc_integer:6);
              end;
            2:begin seek(int2,0);
                     seek(int2,cursor);
                    read(int2,arc_real);
                    write(out,arc_real:6:2);
              end;
            end;
       end;
     writeln(out);
    end;

   close(bound);close(out);
   case k of
   1:close(int1);
   2:close(int2);
   end;

300:end;


begin (*main*)

 10: ClrScr;
   gotoxy(10,4);
writeln('***********************************************************');
   gotoxy(10,5); writeln('*                                                         *');
   gotoxy(10,6); writeln('*  1==> Input BOUNDARY file                               *');
   gotoxy(10,7); writeln('*  2==> Translate from ARC/INFO text to ***.trn file.     *');
   gotoxy(10,8); writeln('*           for example: aspect,flow,cover.....          *');
   gotoxy(10,9); writeln('*  3==> Coding each cell from upperleft to lowerright     *');
   gotoxy(10,10);writeln('*  4==> Search Outlet CELL & Check FLOW DIRECTION
*');
   gotoxy(10,11);writeln('*  5==> Calculate receiving cell                          *');
```

```
    gotoxy(10,12);writeln('*  6==> Output the TEXT file                    *');
    gotoxy(10,13);writeln('*  7==> Output the ARC/INFO ASCII text file     *');
    gotoxy(10,14);writeln('*  0==> End of the procedure                    *');
    gotoxy(10,15);writeln('*                                               *');

gotoxy(10,16);writeln('*****************************************************');
    gotoxy(10,18);write('Please enter selection : ');
    readln(i);

    case i of
    1:input_boundary;
    2:translate;
    3:codeing;
    4:check_flow_and_aspect_direction;
    5:calculate_receiving_cell;
    6:write_text_file;
    7:write_ascii_format;
    0:goto 20;
    end;

    goto 10;


20:end.
```

APPENDIX B:

PROGRAM OF INTERFACE -- PART II

ARC/INFO TO AGNPS

```
program GIS_ARC_INFO_2_AGNPS;

uses Crt;

const division = '000';
     duration = 24.0;
     storm_type='I';
     format=2;

var
    area,rainfall,r_index:real;

    bound,code,receive,aspect,soiltext:file of integer;
    curve,shape,slp_len,slp_len_tran:file of integer;
    fert_level,fert_avail:file of integer;
    point_source,gully_source,cod,impound:file of integer;
    channel_idx:file of integer;
    k_factor,c_factor,p_factor,slope:file of real;
    surface_condition,manning:file of real;

    value_soiltext,value_scs,value_shape,value_slp_len:integer;
    value_fl,value_fa,value_point_source,value_cod:integer;
    value_gully_source,value_impound,value_channel_idx:integer;
    value_k,value_c,value_p,value_slope:real;
    value_surface_condition,value_manning:real;

    write_cell_code,write_receive_cell,write_aspect:integer;
    write_soiltext,write_scs,write_shape,write_slp_len:integer;
    write_fl,write_fa,write_point_source,write_cod:integer;
    write_gully_source,write_impound,write_channel_idx:integer;
    write_k,write_c,write_p,write_slope:real;
    write_surface_condition,write_manning:real;

    answer_soiltext,answer_curve,answer_shape,answer_slp_len:char;
    answer_fl,answer_fa,answer_point_source,answer_cod:char;
    answer_gully_source,answer_impound:char;
    answer_k,answer_p,answer_scs:char;
    answer_surface_condition,answer_manning:char;

    boundary,cellcode,receive_cell:integer;
    unitcode,cell_no,trans:integer;

    in_name,in_file : string[20];
    out_name,out_file:string[20];
    watershed:string[30];
    description:string[30];
```

```
    i,j,m,n :integer;
    cursor:longint;
    agnps_out:text;

begin  (* main *)
    ClrScr;

gotoxy(10,4);writeln('****************************************************************');
    gotoxy(10,5);writeln('The program is designed to transform GIS text file, which is ');
    gotoxy(10,6);writeln('generated by ARC/INFO GRIDASCII command, to a AGNPS standard
');
    gotoxy(10,7);writeln('input file.');

gotoxy(10,8);writeln('****************************************************************');
    gotoxy(10,10);writeln('The following files are required : ');
    gotoxy(12,11);writeln('1==> Boundary ');
    gotoxy(12,12);writeln('2==> Coding cell number ');
    gotoxy(12,13);writeln('3==> Receiving cell number ');
    gotoxy(40,10);writeln('4==> Land Slope % ');
    gotoxy(40,11);writeln('6==> Croping Factor (C) ');
    gotoxy(40,12);writeln('7==> Aspect ');
    gotoxy(40,13);writeln('8==> Channel Indicator ');

    gotoxy(10,15);writeln('The following files are optional <file/number>');
    gotoxy(12,16);writeln(' 1==> K Factor from USLE ');
    gotoxy(12,17);writeln(' 2==> Soil Texture ');
    gotoxy(12,18);writeln(' 3==> SCS Curve Number ');
    gotoxy(12,19);writeln(' 4==> Slope Shape Factor ');
    gotoxy(12,20);writeln(' 5==> Slope Length ');
    gotoxy(12,21);writeln(' 6==> Manning Coefficient ');
    gotoxy(12,22);writeln(' 7==> Practice Factor (P) ');
    gotoxy(40,16);writeln(' 8==> Surface Condition Const.');
    gotoxy(40,17);writeln(' 9==> Fertilization Level <FL> ');
    gotoxy(40,18);writeln('10==> Incorporation Factor <FA> ');
    gotoxy(40,19);writeln('11==> Point Source Indicatior ');
    gotoxy(40,20);writeln('12==> Gully Source Level ');
    gotoxy(40,21);writeln('13==> Chemical Oxygen Demand <COD> ');
    gotoxy(40,22);writeln('14==> Impoundment Factor ');

    repeat
      gotoxy(10,24);
      writeln(' Hit enter to continue .....');
    until keypressed;
    readln;

    ClrScr;
    gotoxy(10,4);writeln('        INPUT THE REQUIRED GIS FILES   ');
```

```
gotoxy(10,6);writeln('*************************************************');
gotoxy(10,7);write(' Enter the BOUNDARY file [***.trn] : ');
readln(in_file);
in_name:=in_file+'.trn';
assign(bound,in_name);
reset(bound);

gotoxy(10,9);write(' Enter the CODING CELL file [***.trn] : ');
readln(in_file);
in_name:=in_file+'.trn';
assign(code,in_name);
reset(code);

gotoxy(10,11);write(' Enter the RECEIVING CELL file [***.trn] : ');
readln(in_file);
in_name:=in_file+'.trn';
assign(receive,in_name);
reset(receive);

gotoxy(10,13);write(' Enter the LAND SLOPE file [***.trn] : ');
readln(in_file);
in_name:=in_file+'.trn';
assign(slope,in_name);
reset(slope);

gotoxy(10,15);write(' Enter the C factor file [***.trn] : ');
readln(in_file);
in_name:=in_file+'.trn';
assign(c_factor,in_name);
reset(c_factor);

gotoxy(10,17);write(' Enter the ASPECT file [***.trn] : ');
readln(in_file);
in_name:=in_file+'.trn';
assign(aspect,in_name);
reset(aspect);

gotoxy(10,19);write(' Enter the Channel Indicator file [***.trn] : ');
readln(in_file);
in_name:=in_file+'.trn';
assign(channel_idx,in_name);
reset(channel_idx);

ClrScr;
gotoxy(10,4);writeln('           INPUT THE OPTIONAL GIS FILES  ');
gotoxy(10,6);writeln('*************************************************');
gotoxy(10,7);write('   Do you have a K factor file ? <y/n> : ');
```

```
readln(answer_k);
if answer_k='y' then
  begin
    gotoxy(10,8);write('   Enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(k_factor,in_name);
    reset(k_factor);
  end
 else
  begin
    gotoxy(10,8);write('   Please input the K factor : ');
    readln(value_k);
  end;

gotoxy(10,10);writeln('************************************************');
gotoxy(10,11);write('   Do you have a P factor file ? <y/n> : ');
readln(answer_p);
if answer_p='y' then
   begin
    gotoxy(10,12);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(p_factor,in_name);
    reset(p_factor);
   end
  else
   begin
    gotoxy(10,12);write('   Please input the P Factor : ');
    readln(value_p);
   end;

gotoxy(10,14);writeln('************************************************');
gotoxy(10,15);write('   Do you have a Soil Texture file ? <y/n> : ');
readln(answer_soiltext);
if answer_soiltext='y' then
  begin
    gotoxy(10,16);write('   Enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(soiltext,in_name);
    reset(soiltext);
  end
 else
  begin
    gotoxy(10,16);write('   Enter the Soil Texture Code : ');
    readln(value_soiltext);
```

```
  end;

gotoxy(10,18);writeln('**************************************************');
gotoxy(10,19);write('   Do you have a SCS curve number file ? <y/n> : ');
readln(answer_scs);
if answer_scs='y' then
   begin
     gotoxy(10,20);write('   Please enter the file name [***.trn] : ');
     readln(in_file);
     in_name:=in_file+'.trn';
     assign(curve,in_name);
     reset(curve);
   end
  else
   begin
     gotoxy(10,20);write('   Please input the SCS curve number : ');
     readln(value_scs);
   end;

gotoxy(10,22);writeln('**************************************************');
gotoxy(10,23);write('   Do you have a Slope Shape file ? <y/n> : ');
readln(answer_shape);
if answer_shape='y' then
   begin
     gotoxy(10,24);write('   Please enter the file name [***.trn] : ');
     readln(in_file);
     in_name:=in_file+'.trn';
     assign(shape,in_name);
     reset(shape);
   end
  else
   begin
     gotoxy(10,24);write('   Please input the Slope Shape : ');
     readln(value_shape);
   end;

ClrScr;
gotoxy(10,4);writeln('**************************************************');
gotoxy(10,5);write('   Do you have a Slope Length file ? <y/n> : ');
readln(answer_slp_len);
if answer_slp_len='y' then
   begin
     gotoxy(10,6);write('   Please enter the file name [***.trn] : ');
     readln(in_file);
     in_name:=in_file+'.trn';
     assign(slp_len,in_name);
     reset(slp_len);
```

```
  end
 else
  begin
    gotoxy(10,6);write('   Please input the Slope Length : ');
    readln(value_slp_len);
  end;


gotoxy(10,8);writeln('**************************************************');
gotoxy(10,9);write('   Do you have a Manning Coefficient file ? <y/n> : ');
readln(answer_manning);
if answer_manning='y' then
  begin
    gotoxy(10,10);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(manning,in_name);
    reset(manning);
  end
 else
  begin
    gotoxy(10,10);write('   Please input the Manning Coefficient : ');
    readln(value_manning);
  end;

gotoxy(10,12);writeln('**************************************************');
gotoxy(10,13);write('   Do you have a Surface Condition Constant file ? <y/n> : ');
readln(answer_surface_condition);
if answer_surface_condition='y' then
  begin
    gotoxy(10,14);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(surface_condition,in_name);
    reset(surface_condition);
  end
 else
  begin
    gotoxy(10,14);write('   Please input the Surface Condition Constant : ');
    readln(value_surface_condition);
  end;

gotoxy(10,16);writeln('**************************************************');
gotoxy(10,17);write('   Do you have a Fertilization Level file ? <y/n> : ');
readln(answer_fl);
if answer_fl='y' then
  begin
```

```
    gotoxy(10,18);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(fert_level,in_name);
    reset(fert_level);
  end
 else
  begin
    gotoxy(10,18);write('   Please input the Fertilization Level : ');
    readln(value_fl);
  end;

gotoxy(10,20);writeln('**************************************************');
gotoxy(10,21);write('  Do you have a Fertilizer Incorporation factor file ? <y/n> : ');
readln(answer_fa);
if answer_fa='y' then
  begin
    gotoxy(10,22);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(fert_avail,in_name);
    reset(fert_avail);
  end
 else
  begin
    gotoxy(10,22);write('   Please input the Fertilizer Incorporation factor : ');
    readln(value_fa);
  end;

ClrScr;
gotoxy(10,4);writeln('**************************************************');
gotoxy(10,5);write('  Do you have a Point Source Indicator file ? <y/n> : ');
readln(answer_point_source);
if answer_point_source='y' then
  begin
    gotoxy(10,6);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(point_source,in_name);
    reset(point_source);
  end
 else
  begin
    gotoxy(10,6);write('   Please input the Point Source Indicator : ');
    readln(value_point_source);
  end;
```

```
gotoxy(10,8);writeln('**************************************************');
gotoxy(10,9);write('   Do you have a Gully Source Level file ? <y/n> : ');
readln(answer_gully_source);
if answer_gully_source='y' then
  begin
    gotoxy(10,10);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(gully_source,in_name);
    reset(gully_source);
  end
 else
  begin
    gotoxy(10,10);write('   Please input the Gully Source Level : ');
    readln(value_gully_source);
  end;

gotoxy(10,12);writeln('**************************************************');
gotoxy(10,13);write('   Do you have a Chemical Oxygen Demand file ? <y/n> : ');
readln(answer_cod);
if answer_cod='y' then
  begin
    gotoxy(10,14);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(cod,in_name);
    reset(cod);
  end
 else
  begin
    gotoxy(10,14);write('   Please input the Chemical Oxygen Demand : ');
    readln(value_cod);
  end;

gotoxy(10,16);writeln('**************************************************');
gotoxy(10,17);write('   Do you have a Impoundment factor file ? <y/n> : ');
readln(answer_impound);
if answer_impound='y' then
  begin
    gotoxy(10,18);write('   Please enter the file name [***.trn] : ');
    readln(in_file);
    in_name:=in_file+'.trn';
    assign(impound,in_name);
    reset(impound);
  end
 else
  begin
```

```
      gotoxy(10,18);write('   Please input the Impoundment Factor : ');
      readln(value_impound);
    end;

  ClrScr;

gotoxy(10,4);writeln('======================================
=============');
  gotoxy(10,5);writeln('            UNIT system               ');

gotoxy(10,6);writeln('======================================
=============');
  gotoxy(10,8);writeln('      1. MKS unit system <Metric>              ');
  gotoxy(10,9);writeln('      2. CGS unit system <English>             ');

gotoxy(10,11);writeln('======================================
=============');
  gotoxy(10,13);write('   Please choose the unit system : ');
  readln(unitcode);

  ClrScr;

gotoxy(10,4);writeln('======================================
=============');
  gotoxy(10,5);writeln('      AGNPS standard data file :              ');

gotoxy(10,6);writeln('======================================
=============');
  gotoxy(10,8);write('Enter the output AGNPS file name <***.dat> : ');
  readln(out_file);
  out_name:=out_file+'.dat';
  assign(agnps_out,out_name);
  rewrite(agnps_out);


gotoxy(10,12);writeln('======================================
=============');
  gotoxy(10,13);writeln('      Watershed Data Input                ');

gotoxy(10,14);writeln('======================================
=============');
  gotoxy(10,15);write('Enter the Watershed Name : ');
  readln(watershed);
  gotoxy(10,16);write('Enter the description : ');
  readln(description);
  gotoxy(10,17);write('Area of each cell <acres/m^2> : ');
  readln(area);
```

```
gotoxy(10,18);write('Number of total cells : ');
readln(cell_no);
gotoxy(10,19);write('Precipitation <inch/mm> : ');
readln(rainfall);
gotoxy(10,20);write('R_index : ');
readln(r_index);

writeln(agnps_out,watershed);
if unitcode=1 then
  begin
    area:=area/4046.85;
    rainfall:=rainfall/25.4;
    r_index:=r_index/1.7389;
  end;
writeln(agnps_out,area:4:1,cell_no:4,rainfall:6:1,r_index:6:1,
'     ',format:1,'  ',duration:4:1,division,'  ',description:30);


gotoxy(10,22);write('How many row , column in GIS TEXT file : ');
readln(m,n);

if unitcode=1 then
 begin
  if answer_slp_len='y' then
     for i:=1 to m do
       for j:=1 to n do
         begin
           ClrScr;
           gotoxy(10,4);writeln('The Slope Length file is MKS unit system, and need to be ');
           gotoxy(10,5);writeln('translated to CGS unit system.  ');
           gotoxy(10,6);write('Please give the name for translated slope length file : ');
           readln(in_file);
           in_name:=in_file+'.trn';
           assign(slp_len_tran,in_name);
           rewrite(slp_len_tran);

           cursor:=(i-1)*n+j-1;
           seek(slp_len,0);
           seek(slp_len,cursor);
           read(slp_len,trans);
           trans:=trunc(trans/0.3048);
           write(slp_len_tran,trans);
         end
   else
     value_slp_len:=trunc(value_slp_len/0.3048);
 end;
```

```
for i:=1 to m do
 for j:=1 to n do
    begin
      read(bound,boundary);
      if boundary=1 then
        begin
          cursor:=(i-1)*n+j-1;

        seek(code,0);
          seek(code,cursor);
          read(code,write_cell_code);

        seek(receive,0);
          seek(receive,cursor);
          read(receive,write_receive_cell);

        seek(slope,0);
          seek(slope,cursor);
          read(slope,write_slope);

        seek(c_factor,0);
          seek(c_factor,cursor);
          read(c_factor,write_c);

        seek(aspect,0);
          seek(aspect,cursor);
          read(aspect,write_aspect);

        seek(channel_idx,0);
        seek(channel_idx,cursor);
        read(channel_idx,write_channel_idx);

        if answer_k='y' then
          begin
            seek(k_factor,0);
            seek(k_factor,cursor);
            read(k_factor,write_k);
          end
         else
            write_k:=value_k;

        if answer_soiltext='y' then
          begin
            seek(soiltext,0);
            seek(soiltext,cursor);
            read(soiltext,write_soiltext);
          end
```

```
else
  write_soiltext:=value_soiltext;

if answer_scs='y' then
 begin
  seek(curve,0);
  seek(curve,cursor);
  read(curve,write_scs);
 end
else
  write_scs:=value_scs;

if answer_shape='y' then
 begin
  seek(shape,0);
  seek(shape,cursor);
  read(shape,write_shape);
 end
else
  write_shape:=value_shape;

if answer_slp_len='y' then
  if unitcode=1 then
    begin
      seek(slp_len_tran,0);
      seek(slp_len_tran,cursor);
      read(slp_len_tran,write_slp_len);
    end
   else
    begin
      seek(slp_len,0);
      seek(slp_len,cursor);
      read(slp_len,write_slp_len);
    end
  else
   write_slp_len:=value_slp_len;

if answer_fl='y' then
 begin
  seek(fert_level,0);
  seek(fert_level,cursor);
  read(fert_level,write_fl);
 end
else
  write_fl:=value_fl;

if answer_fa='y' then
```

```
 begin
   seek(fert_avail,0);
   seek(fert_avail,cursor);
   read(fert_avail,write_fa);
 end
else
   write_fa:=value_fa;

if answer_point_source='y' then
 begin
   seek(point_source,0);
   seek(point_source,cursor);
   read(point_source,write_point_source);
 end
else
   write_point_source:=value_point_source;

if answer_gully_source='y' then
 begin
   seek(gully_source,0);
   seek(gully_source,cursor);
   read(gully_source,write_gully_source);
 end
else
   write_gully_source:=value_gully_source;

if answer_cod='y' then
 begin
   seek(cod,0);
   seek(cod,cursor);
   read(cod,write_cod);
 end
else
   write_cod:=value_cod;

if answer_impound='y' then
 begin
   seek(impound,0);
   seek(impound,cursor);
   read(impound,write_impound);
 end
else
   write_impound:=value_impound;


if answer_manning='y' then
 begin
```

```
          seek(manning,0);
          seek(manning,cursor);
          read(manning,write_manning);
        end
       else
          write_manning:=value_manning;

       if answer_p='y' then
        begin
          seek(p_factor,0);
          seek(p_factor,cursor);
          read(p_factor,write_p);
        end
       else
          write_p:=value_p;

       if answer_surface_condition='y' then
        begin
          seek(surface_condition,0);
          seek(surface_condition,cursor);
          read(surface_condition,write_surface_condition);
        end
       else
          write_surface_condition:=value_surface_condition;


        writeln(agnps_out,write_cell_code:4,division,
              write_receive_cell:4,division,write_aspect:2,
              write_scs:4,
                  write_slope:5:1,write_shape:2,write_slp_len:4,
              write_manning:5:3,write_k:4:2,write_c:4:2,
                  write_p:5:2,write_surface_condition:4:2,
              write_soiltext:2,write_fl:2,write_fa:4,
                  write_point_source:2,write_gully_source:4,
              write_cod:4,write_impound:3,write_channel_idx:2);
      end;
  end;


close(bound);close(code);close(receive);close(aspect);
close(c_factor);close(channel_idx);close(agnps_out);

if answer_k='y' then close(k_factor);
if answer_soiltext='y' then close(soiltext);
if answer_curve='y' then close(curve);
if answer_shape='y' then close(shape);
if answer_slp_len='y' then close(slp_len);
```

```
    if answer_fl='y' then close(fert_level);
    if answer_fa='y' then close(fert_avail);
    if answer_point_source='y' then close (point_source);
    if answer_gully_source='y' then close (gully_source);
    if answer_cod='y' then close(cod);
    if answer_impound='y' then close(impound);
    if answer_manning='y' then close(manning);
    if answer_p='y' then close(p_factor);
    if answer_surface_condition='y' then close(surface_condition);

end.
```

APPENDIX C:

PROGRAM OF INTERFACE -- PART III

AGNPS TO ARC/INFO

```
Program agnps_2_gis_arc_info;

uses Crt;

const
    outfile_ext='.trn';

label 10,20;

type soil_string=record
              cell_number:string[4];
              extend:string[4];
              drain_area:string[5];
              runoff_volume:string[7];
              up_runoff:string[7];
              up_peak:string[6];
              down_runoff:string[7];
              down_peak:string[6];
              above_runoff:string[6];
              cell_erosion:string[7];
              above_sed:string[7];
              within_sed:string[7];
              sed_yield:string[7];
              sed_deposit:string[6];
              end;

    nutrient_string=record
                 cell_number:string[4];
                 extend:string[4];
                 drain_area:string[5];
                 n_loss_sed_within:string[7];
                 n_loss_sed_outlet:string[7];
                 n_loss_water_within:string[7];
                 n_loss_water_outlet:string[7];
                 n_loss_water_concen:string[6];
                 p_loss_sed_within:string[7];
                 p_loss_sed_outlet:string[7];
                 p_loss_water_within:string[7];
                 p_loss_water_outlet:string[7];
                 p_loss_water_concen:string[6];
                 cod_water_within:string[7];
                 cod_water_outlet:string[7];
                 cod_water_concen:string[6];
                 end;

    soil_header=record
```

```
            cell_number:integer;
            extend:integer;
            drain_area:integer;
            runoff_volume:real;
            up_runoff:real;
            up_peak:integer;
            down_runoff:real;
            down_peak:integer;
            above_runoff:real;
            cell_erosion:real;
            above_sed:real;
            within_sed:real;
            sed_yield:real;
            sed_deposit:integer;
            end;

    nutrient_header=record
                cell_number:integer;
                extend:integer;
                drain_area:integer;
                n_loss_sed_within:real;
                n_loss_sed_outlet:real;
                n_loss_water_within:real;
                n_loss_water_outlet:real;
                n_loss_water_concen:integer;
                p_loss_sed_within:real;
                p_loss_sed_outlet:real;
                p_loss_water_within:real;
                p_loss_water_outlet:real;
                p_loss_water_concen:integer;
                cod_water_within:real;
                cod_water_outlet:real;
                cod_water_concen:integer;
                end;


var
    in_name,out_name:string[20];
    ag_gis,soil_loss,nutrient_loss:string[20];
    watershed_cod:string[20];
    header:string[50];
    code:integer;
    part,cursor:integer;
    total_no:integer;
    i,j:integer;
    m,n:integer;
```

```
    soil_head:soil_string;
    nutrient_head:nutrient_string;
    soil:soil_header;
    nutrient:nutrient_header;
    value_integer:integer;
    value_real:real;

    int_agnps:text;
    cellcode:file of integer;
    out_soilloss,out_nutrient:text;
    out_soilloss_item1,out_nutrient_item1:file of integer;
    out_soilloss_item2,out_nutrient_item2:file of real;


procedure soil_loss_gis;

label 100,101;

var item:integer;
   n_row,n_col:integer;
   i,j:integer;
   out_file:string[20];
   m,n:integer;

begin

100: ClrScr;
    gotoxy(10,4);writeln('*************************************************');
    gotoxy(10,5);writeln(' Translate Soil Loss/Sediment to ARC/INFO text file  ');
    gotoxy(10,6);writeln('*************************************************');
    gotoxy(10,7); writeln(' 1 ===> Runoff Drainage Area (acres)');
    gotoxy(10,8); writeln(' 2 ===> Runoff Volume/Overland Runoff (in.)');
    gotoxy(10,9); writeln(' 3 ===> Upstream Runoff (in.)');
    gotoxy(10,10);writeln(' 4 ===> Upstream Peak Flow (cfs)');
    gotoxy(10,11);writeln(' 5 ===> Downstream Runoff (in.)');
    gotoxy(10,12);writeln(' 6 ===> Peak Rate/Downstream Peak Flow (cfs)');
    gotoxy(10,13);writeln(' 7 ===> Runoff generated above (%) ');
    gotoxy(10,14);writeln(' 8 ===> Cell Erosion (t/a) ');
    gotoxy(10,15);writeln(' 9 ===> Sediment generated above (tons)');
    gotoxy(10,16);writeln('10 ===> Sediment generated within cell (tons)');
    gotoxy(10,17);writeln('11 ===> Sediment Yield (tons)');
    gotoxy(10,18);writeln('12 ===> Sediment Deposit (%)');
    gotoxy(10,19);writeln(' 0 ===> Quit ');
    gotoxy(10,21);write('Please enter selection : ');
    readln(item);
    if item=0 then goto 101;
```

```
gotoxy(10,23);write('Please name the output Soil Loss file :');
readln(out_file);
out_name:=out_file+outfile_ext;

if item in [1,4,6,12] then
  begin
    assign(out_soilloss_item1,out_name);
    rewrite(out_soilloss_item1);
  end
 else
  if item in [2,3,5,7,8,9,10,11] then
    begin
      assign(out_soilloss_item2,out_name);
      rewrite(out_soilloss_item2);
    end
   else
    begin
      gotoxy(10,24);
      writeln(' ***** Wrong Selection ***** ');
      goto 100;
    end;

gotoxy(10,25); write('Please enter #_row   #_column : ');
readln(n_row,n_col);

reset(out_soilloss);
reset(cellcode);

cursor:=0;

m:=n_row;
n:=n_col;

value_integer:=0;
value_real:=0.0;

for i:=1 to m do
 begin
  for j:=1 to n do
    begin
      cursor:=(i-1)*n+j-1;
      seek(cellcode,0);
      seek(cellcode,cursor);
      read(cellcode,code);

      if code<>0 then
       begin
```

```
        with soil do
          begin
          readln(out_soilloss,cell_number,drain_area,
                runoff_volume,up_runoff,up_peak,
                down_runoff,down_peak,above_runoff,
                cell_erosion,above_sed,within_sed,
                sed_yield,sed_deposit);
          case item of
          1:write(out_soilloss_item1,drain_area);
          2:write(out_soilloss_item2,runoff_volume);
          3:write(out_soilloss_item2,up_runoff);
          4:write(out_soilloss_item1,up_peak);
          5:write(out_soilloss_item2,down_runoff);
          6:write(out_soilloss_item1,down_peak);
          7:write(out_soilloss_item2,above_runoff);
          8:write(out_soilloss_item2,cell_erosion);
          9:write(out_soilloss_item2,above_sed);
         10:write(out_soilloss_item2,within_sed);
         11:write(out_soilloss_item2,sed_yield);
         12:write(out_soilloss_item1,sed_deposit);
         end;
         end
       end
      else
        if item in [1,4,6,12] then
          write(out_soilloss_item1,value_integer)
         else
          write(out_soilloss_item2,value_real);

    end;
   end;

  close(out_soilloss); close(cellcode);
  if item in [1,4,6,12] then close(out_soilloss_item1)
    else close(out_soilloss_item2);
  goto 100;

101:end; (* end of procedure soil_loss_gis*)


procedure nutrient_loss_gis;

label 200,201;

var item:integer;
   n_row,n_col:integer;
   i,j:integer;
```

```
   out_file:string[20];

begin

200: ClrScr;
    gotoxy(10,4);writeln('*****************************************************');
    gotoxy(10,5);writeln('    Translate Nutrient Loss to ARC/INFO text file    ');
    gotoxy(10,6);writeln('*****************************************************');
    gotoxy(10,7); writeln(' 1 ===> Runoff Drainage Area');
    gotoxy(10,8); writeln(' 2 ===> N loss in Sediment within cell (lbs/a) ');
    gotoxy(10,9); writeln(' 3 ===> N loss in Sediment at cell outlet (lbs/a) ');
    gotoxy(10,10);writeln(' 4 ===> N loss in Water within cell (lbs/a)');
    gotoxy(10,11);writeln(' 5 ===> N loss in Water at cell outlet (lbs/a)');
    gotoxy(10,12);writeln(' 6 ===> N loss in Water, concentration (ppm) ');
    gotoxy(10,13);writeln(' 7 ===> P loss in Sediment within cell (lbs/a) ');
    gotoxy(10,14);writeln(' 8 ===> P loss in Sediment at cell outlet (lbs/a) ');
    gotoxy(10,15);writeln(' 9 ===> P loss in Water within cell (lbs/a)');
    gotoxy(10,16);writeln('10 ===> P loss in Water at cell outlet (lbs/a)');
    gotoxy(10,17);writeln('11 ===> P loss in Water, concentration (ppm) ');
    gotoxy(10,18);writeln('12 ===> COD loss in Water within cell (lbs/a)');
    gotoxy(10,19);writeln('13 ===> COD loss in Water at cell outlet (lbs/a)');
    gotoxy(10,20);writeln('14 ===> COD loss in Water, concentration (ppm) ');
    gotoxy(10,21);writeln(' 0 ===> Quit ');
    gotoxy(10,22);write('Please enter selection : ');
    readln(item);
    if item=0 then goto 201;

    gotoxy(10,24);write('Please name the output Nutrient file : ');
    readln(out_file);
    out_name:=out_file+outfile_ext;

    if item in [1,6,11,14] then
      begin
        assign(out_nutrient_item1,out_name);
        rewrite(out_nutrient_item1);
      end
     else
      if item in [2,3,4,5,7,8,9,10,12,13] then
        begin
          assign(out_nutrient_item2,out_name);
          rewrite(out_nutrient_item2);
        end
       else
        begin
          gotoxy(10,24);
          writeln(' ***** Wrong Selection ***** ');
          goto 200;
```

```
  end;


gotoxy(10,25);write('Please enter #_row   #_column : ');
readln(n_row,n_col);

reset(out_nutrient);
reset(cellcode);

cursor:=0;

m:=n_row;
n:=n_col;

value_integer:=0;
value_real:=0.0;

for i:=1 to m do
 for j:=1 to n do
  begin
   cursor:=(i-1)*n+j-1;
   seek(cellcode,0);
   seek(cellcode,cursor);
   read(cellcode,code);
   if code<>0 then
     begin
      with nutrient do
       begin
        readln(out_nutrient,cell_number,drain_area,
               n_loss_sed_within,n_loss_sed_outlet,
               n_loss_water_within,n_loss_water_outlet,
               n_loss_water_concen,
               p_loss_sed_within,p_loss_sed_outlet,
               p_loss_water_within,p_loss_water_outlet,
               p_loss_water_concen,
               cod_water_within,cod_water_outlet,
               cod_water_concen);
        case item of
        1:write(out_nutrient_item1,drain_area);
        2:write(out_nutrient_item2,n_loss_sed_within);
        3:write(out_nutrient_item2,n_loss_sed_outlet);
        4:write(out_nutrient_item2,n_loss_water_within);
        5:write(out_nutrient_item2,n_loss_water_outlet);
        6:write(out_nutrient_item1,n_loss_water_concen);
        7:write(out_nutrient_item2,p_loss_sed_within);
        8:write(out_nutrient_item2,p_loss_sed_outlet);
        9:write(out_nutrient_item2,p_loss_water_within);
```

```
          10:write(out_nutrient_item2,p_loss_water_outlet);
          11:write(out_nutrient_item1,p_loss_water_concen);
          12:write(out_nutrient_item2,cod_water_within);
          13:write(out_nutrient_item2,cod_water_outlet);
          14:write(out_nutrient_item1,cod_water_concen);
          end;
          end;
        end
      else
        if item in [1,6,11,14] then
          write(out_nutrient_item1,value_integer)
         else write(out_nutrient_item2,value_real);

    end;

  close(cellcode);  close(out_nutrient);
  if item in [1,6,11,14] then close(out_nutrient_item1)
    else close(out_nutrient_item2);
  goto 200;


201:end; (* end of procedure nutrient_loss_gis *)



begin (*main*)

  ClrScr;
  gotoxy(10,4); writeln('***************************************************');
  gotoxy(10,5); writeln('  The program was designed to convert AGNPS output');
  gotoxy(10,6); writeln('  GIS file back to ARC/INFO ');
  gotoxy(10,7); writeln('***************************************************');
  gotoxy(10,9); write('  Please enter the AGNPS_GIS output file : ');
  readln(ag_gis);
  assign(int_agnps,ag_gis);
  reset(int_agnps);

  gotoxy(10,11); write('  Please enter the total cell # : ');
  readln(total_no);

  gotoxy(10,13); write('  Please give the name for SOIL LOSS output : ');
  readln(soil_loss);
  out_name:=soil_loss+'.dat';
  assign(out_soilloss,out_name);
  rewrite(out_soilloss);
```

```
gotoxy(10,15); write('  Please give the name for NUTRIENT LOSS output : ');
readln(nutrient_loss);
out_name:=nutrient_loss+'.dat';
assign(out_nutrient,out_name);
rewrite(out_nutrient);

readln(int_agnps,header);

gotoxy(10,17); writeln('     Part I : ', header);

m:=total_no;

for i:=1 to m do
  begin
    with soil_head do
    begin
      readln(int_agnps,cell_number,extend,drain_area,
      runoff_volume,up_runoff,up_peak,
      down_runoff,down_peak,above_runoff,
      cell_erosion,above_sed,within_sed,
      sed_yield,sed_deposit);

      if runoff_volume='*******' then runoff_volume:='  -9999';
      if up_runoff='*******' then up_runoff:='  -9999';
      if up_peak='******' then up_peak:=' -9999';
      if down_runoff='*******' then down_runoff:='  -9999';
      if down_peak='******' then down_peak:=' -9999';
      if above_runoff='******' then above_runoff:=' -9999';
      if cell_erosion='*******' then cell_erosion:='  -9999';
      if above_sed='*******' then above_sed:='  -9999';
      if within_sed='*******' then within_sed:='  -9999';
      if sed_yield='*******' then sed_yield:='  -9999';
      if sed_deposit='******' then sed_deposit:=' -9999';

     writeln(out_soilloss,cell_number,' ',drain_area,' ',
      runoff_volume,' ',up_runoff,' ',up_peak,' ',
      down_runoff,' ',down_peak,' ',above_runoff,' ',
      cell_erosion,' ',above_sed,' ',within_sed,' ',
      sed_yield,' ',sed_deposit);
    end;
  end;


close(out_soilloss);

readln(int_agnps,header);
gotoxy(10,19); writeln('     Part II : ',header);
```

```
for i:=1 to m do
  with nutrient_head do
    begin
    readln(int_agnps.cell_number.extend.drain_area.
      n_loss_sed_within,n_loss_sed_outlet,
      n_loss_water_within,n_loss_water_outlet,
      n_loss_water_concen,
      p_loss_sed_within,p_loss_sed_outlet,
      p_loss_water_within,p_loss_water_outlet,
      p_loss_water_concen,
      cod_water_within,cod_water_outlet,
      cod_water_concen);

    if n_loss_sed_within='*******' then n_loss_sed_within:=' -9999';
    if n_loss_sed_outlet='*******' then n_loss_sed_outlet:=' -9999';
    if n_loss_water_within='*******' then n_loss_water_within:=' -9999';
    if n_loss_water_outlet='*******' then n_loss_water_outlet:=' -9999';
    if n_loss_water_concen='******' then n_loss_water_concen:=' -9999';
    if p_loss_sed_within='*******' then p_loss_sed_within:=' -9999';
    if p_loss_sed_outlet='*******' then p_loss_sed_outlet:=' -9999';
    if p_loss_water_within='*******' then p_loss_water_within:=' -9999';
    if p_loss_water_outlet='*******' then p_loss_water_outlet:=' -9999';
    if p_loss_water_concen='******' then p_loss_water_concen:=' -9999';
    if cod_water_within='*******' then cod_water_within:=' -9999';
    if cod_water_outlet='*******' then cod_water_outlet:=' -9999';
    if cod_water_concen='******' then cod_water_concen:=' -9999';

    writeln(out_nutrient,cell_number,' ',drain_area,' ',
      n_loss_sed_within,' ',n_loss_sed_outlet,' ',
      n_loss_water_within,' ',n_loss_water_outlet,' ',
      n_loss_water_concen,' ',
      p_loss_sed_within,' ',p_loss_sed_outlet,' ',
      p_loss_water_within,' ',p_loss_water_outlet,' ',
      p_loss_water_concen,' ',
      cod_water_within,' ',cod_water_outlet,' ',
      cod_water_concen);

  end;

close(int_agnps); close(out_nutrient);

gotoxy(10,21); write(' Please enter watershed code file [***.trn] : ');
readln(watershed_cod);
in_name:=watershed_cod + outfile_ext;
assign(cellcode,in_name);
reset(cellcode);
```

```
10:ClrScr;
  gotoxy(10,5);writeln('*********************************************');
  gotoxy(10,6);writeln(' Convert AGNPS_GIS output file to ARC/INFO text file ');
  gotoxy(10,7);writeln('*********************************************');
  gotoxy(10,9);writeln('     1 ===> Soil Loss and Sediment output ');
  gotoxy(10,10);writeln('     2 ===> Nutrient Loss output ');
  gotoxy(10,11);writeln('     0 ===> quit ');
  gotoxy(10,14);write('     Please enter selection : ');
  readln(part);

  if part=1 then soil_loss_gis
   else if part=2 then nutrient_loss_gis
        else if part=0 then goto 20
               else
                 begin
                 gotoxy(10,14);
                 writeln('*** Wrong Selection ***');
                 goto 10
                 end;
  goto 10;

20:end.
```

APPENDIX D:

SAS PROGRAM AND OUTPUT

```
//stepwise job
//step1 exec sas
//green dd dsn=tw$b69.thesis.dat,unit=disk,disp=shr
//sysin  dd  *

data thesis;
 infile green;
 input y1-y6 locat drain cell x1-x13;
 if locat=1 then y21=y2/40;
 if locat=2 then y21=y2/2.5;
 if locat=1 then y41=y4/40;
 if locat=2 then y41=y4/2.5;
 if locat=1 then y61=y6/40;
 if locat=2 then y61=y6/2.5;


 label y1 = CELL EROSION (t/a)
       y2 = SEDIMENT YIELD (tons)
       y21= SEDIMENT YIELD (t/a)
       y3 = N-LOSS in water (lbs/a)
       y4 = N-LOSS in water (ppm)
       y41= N-LOSS in water (ppm/a)
       y5 = P-LOSS in sediment (lbs/a)
       y6 = P-LOSS in water (ppm)
       y61= P-LOSS in water (ppm/a) ;


 proc stepwise data=thesis;
  title 'STEPWISE ANALYSIS -- Lake Icaria & Dry Run ';
  model y1 = drain cell x1-x9 x13/stepwise;
  model y21= drain cell x1-x9 x13 y1/stepwise;
  model y3 = drain cell x1-x13 y1-y2/stepwise;
  model y41= drain cell x1-x13 y1-y2/stepwise;
  model y5 = drain cell x1-x13 y1-y2/stepwise;
  model y61= drain cell x1-x13 y1-y2/stepwise;
```

STEPWISE ANALYSIS -- Lake Icaria & Dry Run

All variables left in the model are significant at the 0.1500 level.
No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Procedure for Dependent Variable Y1

Step	Variable Entered	Variable Removed	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	X3		1	0.3279	0.3279	86.6562	385.4320	0.0001
2	X7		2	0.0440	0.3719	31.4576	55.2074	0.0001
3	X6		3	0.0121	0.3839	17.7597	15.4285	0.0001
4	X4		4	0.0062	0.3902	11.6440	8.0477	0.0047
5	X5		5	0.0085	0.3987	2.5615	11.1312	0.0009

Summary of Stepwise Procedure for Dependent Variable Y21

Step	Variable Entered	Variable Removed	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	X3		1	0.1139	0.1139	99.3247	101.5400	0.0001
2	X13		2	0.0450	0.1589	56.2260	42.2486	0.0001
3	X6		3	0.0306	0.1895	27.5645	29.7712	0.0001
4	DRAIN		4	0.0127	0.2022	16.8692	12.5068	0.0004
5	Y1		5	0.0099	0.2121	8.9916	9.8401	0.0018
6	X2		6	0.0032	0.2153	7.7661	3.2223	0.0730
7	X1		7	0.0024	0.2178	7.3219	2.4463	0.1182
8	X8		8	0.0023	0.2200	7.0585	2.2690	0.1324

Summary of Stepwise Procedure for Dependent Variable Y3

Step	Variable Entered	Variable Removed	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	X10		1	0.6708	0.6708	693.3530	1609.5197	0.0001
2	X2		2	0.1192	0.7899	159.2447	447.4921	0.0001
3	X9		3	0.0245	0.8145	50.8323	104.2185	0.0001
4	CELL		4	0.0033	0.8178	37.9494	14.2848	0.0002
5	X5		5	0.0014	0.8192	33.6119	6.1225	0.0136
6	X7		6	0.0032	0.8224	21.0686	14.2872	0.0002
7	X8		7	0.0024	0.8248	12.3310	10.6785	0.0011
8	X6		8	0.0015	0.8263	7.6324	6.7104	0.0098
9	Y2		9	0.0010	0.8272	5.3176	4.3407	0.0375

STEPWISE ANALYSIS -- Lake Icaria & Dry Run

All variables left in the model are significant at the 0.1500 level.
No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Procedure for Dependent Variable Y41

Step	Variable Entered	Variable Removed	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	X4		1	0.7937	0.7937	997.8733	3038.8848	0.0001
2	X10		2	0.1037	0.8974	102.4026	797.0535	0.0001
3	X8		3	0.0089	0.9063	27.1953	74.9996	0.0001
4	X13		4	0.0018	0.9080	13.9168	15.1073	0.0001
5	X9		5	0.0007	0.9087	9.9758	5.9111	0.0153
6	X1		6	0.0006	0.9093	7.2021	4.7725	0.0292
7	X5		7	0.0005	0.9098	4.6706	4.5507	0.0332

Summary of Stepwise Procedure for Dependent Variable Y5

Step	Variable Entered	Variable Removed	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	Y1		1	0.9796	0.9796	642.0493	38010.2916	0.0001
2	X3		2	0.0049	0.9846	297.8906	251.9804	0.0001
3	Y2		3	0.0017	0.9863	181.3313	96.7800	0.0001
4	X5		4	0.0006	0.9869	138.2440	38.5589	0.0001
5	X9		5	0.0007	0.9876	90.3117	45.0951	0.0001
6	X6		6	0.0007	0.9883	46.2419	43.8764	0.0001
7	X4		7	0.0003	0.9885	28.8924	18.8473	0.0001
8		X9	6	0.0000	0.9885	28.2779	1.3496	0.2457
9	X7		7	0.0002	0.9887	17.4788	12.6462	0.0004
10	X2		8	0.0001	0.9888	15.6887	3.7580	0.0529
11	X11		9	0.0000	0.9888	14.8280	2.8432	0.0922
12	X10		10	0.0001	0.9889	10.0157	6.8208	0.0092

Summary of Stepwise Procedure for Dependent Variable Y61

Step	Variable Entered	Variable Removed	Number In	Partial R**2	Model R**2	C(p)	F	Prob>F
1	X10		1	0.1499	0.1499	158.7248	139.2792	0.0001
2	X4		2	0.0200	0.1698	138.4941	18.9725	0.0001
3	X9		3	0.0997	0.2696	29.4274	107.5949	0.0001
4	X13		4	0.0128	0.2824	17.1344	14.0760	0.0002
5	X8		5	0.0079	0.2903	10.2974	8.7889	0.0031
6	X5		6	0.0052	0.2956	6.4885	5.8127	0.0161
7	X6		7	0.0035	0.2991	4.5740	3.9317	0.0477

```
//icaria job
//step1 exec sas
//green dd dsn=tw$b69.icaria.sas,unit=disk,disp=shr
//sysin  dd  *

data icaria;
 infile green;
 input x1 x2 x3 x4 x5 x6;
       x21 = x2/40;
       x41 = x4/40;
       x61 = x6/40;
 label x1 = CELL EROSION (t/a)
       x2 = SEDIMENT YIELD (tons)
       x21= SEDIMENT YIELD (tons/a)
       x3 = N-LOSS in water (lbs/a)
       x4 = N-LOSS in water (ppm)
       x41= N-Loss in water (ppm/a)
       x5 = P-LOSS in sediment (lbs/a)
       x6 = P-LOSS in water (ppm)
       x61= P-Loss in water (ppm/a);


proc univariate data=icaria normal plot;
  title 'Lake Icaria Watershed';
  var x1-x6 x21 x41 x61;
```

Univariate Procedure

Variable=X1 CELL EROSION (t/a)

Moments

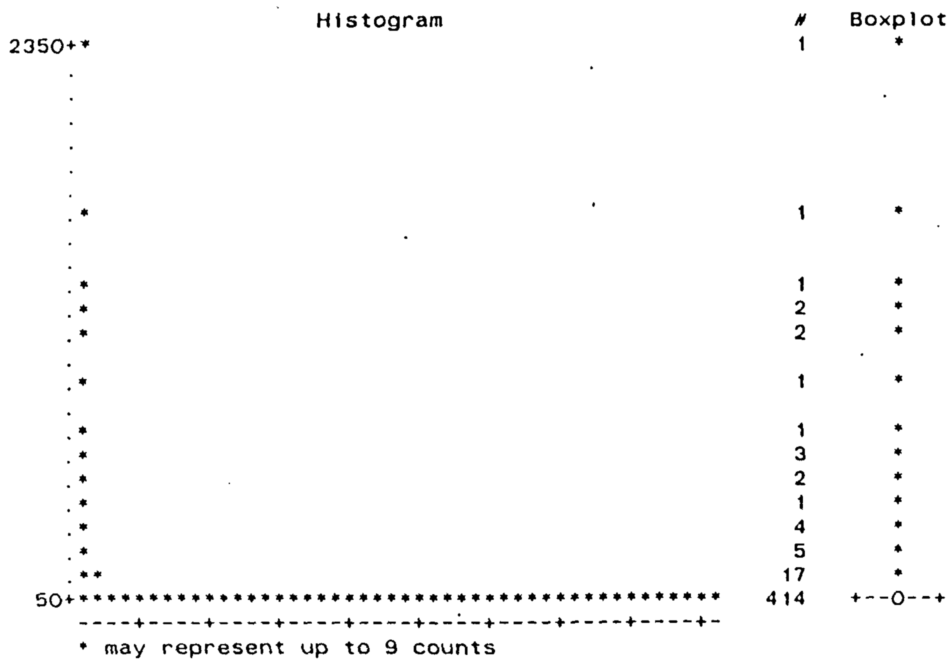
N	455	Sum Wgts	455
Mean	52.11303	Sum	23711.43
Std Dev	203.6938	Variance	41491.15
Skewness	6.787346	Kurtosis	55.31856
USS	20072656	CSS	18836981
CV	390.8691	Std Mean	9.549311
T:Mean=0	5.457256	Prob>|T|	0.0001
Num ^= 0	358	Num > 0	358
M(Sign)	179	Prob>|M|	0.0001
Sgn Rank	32130.5	Prob>|S|	0.0001
W:Normal	0.289969	Prob<W	0.0001

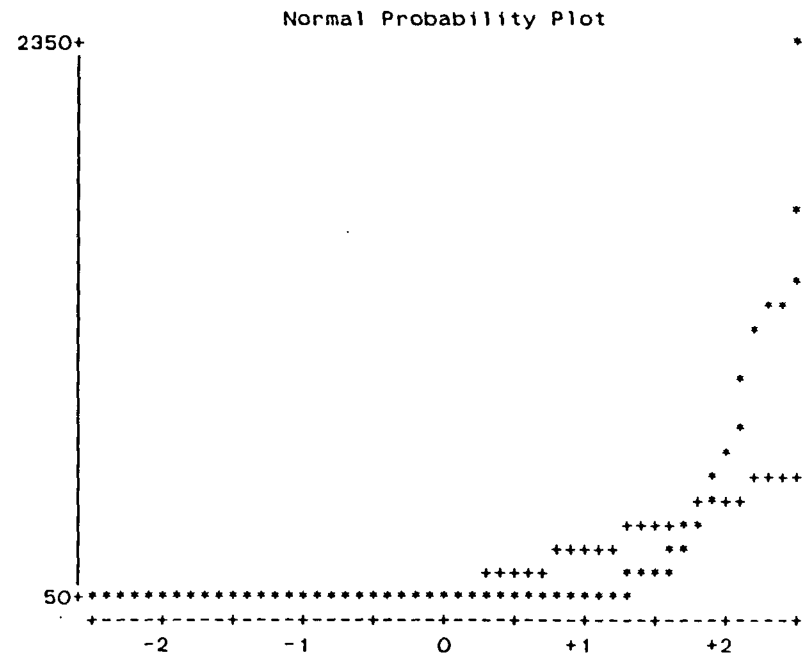
Quantiles(Def=5)

100% Max	2364.74	99%	1213.13
75% Q3	15.12	95%	228.85
50% Med	1.93	90%	78.74
25% Q1	0.15	10%	0
0% Min	0	5%	0
		1%	0
Range	2364.74		
Q3-Q1	14.97		
Mode	0		

Extremes

Lowest	Obs	Highest	Obs
0(	450)	1213.13(	439)
0(	449)	1220.51(	258)
0(	448)	1373.08(	315)
0(	445)	1601.92(	140)
0(	441)	2364.74(	99)





Univariate Procedure

Variable=X2 SEDIMENT YIELD (tons)

Moments

N	455	Sum Wgts	455
Mean	771.5367	Sum	351049.2
Std Dev	1802.514	Variance	3249056
Skewness	2.948223	Kurtosis	8.340602
USS	1.7459E9	CSS	1.4751E9
CV	233.6265	Std Mean	84.50316
T:Mean=0	9.13027	Prob>|T|	0.0001
Num ¬= 0	398	Num > 0	398
M(Sign)	199	Prob>|M|	0.0001
Sgn Rank	39700.5	Prob>|S|	0.0001
W:Normal	0.48722	Prob<W	0.0001

Quantiles(Def=5)

100% Max	9381.02	99%	8682.5
75% Q3	416.75	95%	5676.36
50% Med	34.29	90%	2905.45
25% Q1	1.57	10%	0
0% Min	0	5%	0
		1%	0
Range	9381.02		
Q3-Q1	415.18		
Mode	0		

Extremes

Lowest	Obs	Highest	Obs
0(	439)	8682.5(	298)
0(	435)	9102.09(	443)
0(	425)	9195.07(	270)
0(	424)	9268.21(	266)
0(	418)	9381.02(	215)

```
                Histogram                          #  Boxplot
9250+*                                             4     *
    .*                                             2     *
    .*                                             1     *
    .*                                             3     *
    .*                                             1     *
    .*                                             1     *
    .*                                             5     *
    .*                                             6     *
    .*                                             5     *
4750+*                                             3     *
    .*                                             4     *
    .*                                             6     *
    .*                                             3     *
    .*                                             5     *
    .*                                             6     *
    .*                                             8     0
    .**                                           11     0
    .***                                          22     +
 250+********************************************* 359  +-----+
     ----+----+----+----+----+----+----+----+----+
     * may represent up to 8 counts
```

```
                      Normal Probability Plot
9250+                                                         **
    |                                                       **
    |                                                       *
    |                                                     **
    |                                                     *
    |                                                     *
    |                                                   **
    |                                                 ***
    |                                                **      ++
4750+                                                *    +++
    |                                               ** +++
    |                                              ** ++
    |                                              ***
    |                                            ++++
    |                                         +++  *
    |                                       ++   **
    |                                    +++    **
    |                                 +++     ***
 250+*********************************
     +----+----+----+----+----+----+----+----+----+----+
         -2        -1         0        +1        +2
```

Univariate Procedure

Variable=X3 N-LOSS in water (lbs/a)

Moments

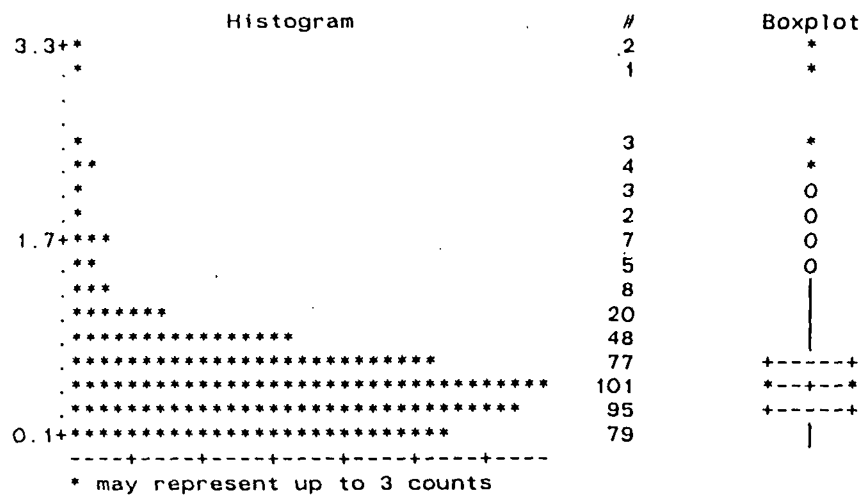
N	455	Sum Wgts	455
Mean	0.583473	Sum	265.48
Std Dev	0.492851	Variance	0.242902
Skewness	2.123857	Kurtosis	6.819294
USS	265.178	CSS	110.2777
CV	84.46865	Std Mean	0.023105
T:Mean=0	25.25284	Prob>|T|	0.0001
Num ¬= 0	429	Num > 0	429
M(Sign)	214.5	Prob>|M|	0.0001
Sgn Rank	46117.5	Prob>|S|	0.0001
W:Normal	0.820844	Prob<W	0.0001

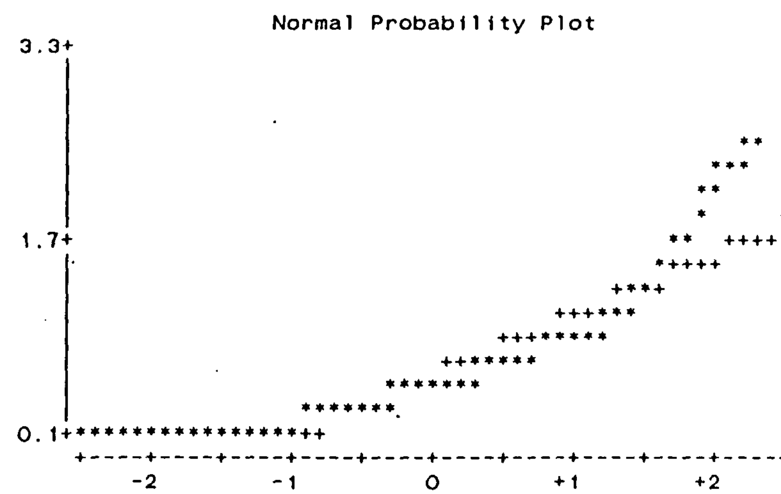
Quantiles(Def=5)

100% Max	3.23	99%	2.55
75% Q3	0.76	95%	1.59
50% Med	0.5	90%	1.01
25% Q1	0.29	10%	0.05
0% Min	0	5%	0
		1%	0
Range	3.23		
Q3-Q1	0.47		
Mode	0		

Extremes

Lowest	Obs	Highest	Obs
0(	454)	2.55(	42)
0(	452)	2.55(	82)
0(	418)	3.09(	26)
0(	417)	3.23(	9)
0(	406)	3.23(	383)





```
                                            Lake Icaria Watershed                    14:11 Thursday, April 8, 1993   4

                                             Univariate Procedure

Variable=X4          N-LOSS in water (ppm)

               Moments                               Quantiles(Def=5)                           Extremes

N               455  Sum Wgts       455     100% Max        4       99%        4      Lowest    Obs     Highest    Obs
Mean       1.175824  Sum            535      75% Q3         1       95%        2          1(    455)       4(       9)
Std Dev    0.505333  Variance  0.255361      50% Med        1       90%        2          1(    454)       4(      26)
Skewness   3.366746  Kurtosis  12.38072      25% Q1         1       10%        1          1(    453)       4(      81)
USS             745  CSS       115.9341       0% Min        1        5%        1          1(    452)       4(      82)
CV         42.97691  Std Mean   0.02369                              1%        1          1(    451)       4(     383)
T:Mean=0   49.63299  Prob>|T|    0.0001     Range           3
Num ^= 0        455  Num > 0        455     Q3-Q1           0
M(Sign)       227.5  Prob>|M|    0.0001     Mode            1
Sgn Rank      51870  Prob>|S|    0.0001
W:Normal   0.396591  Prob<W      0.0001

                 Histogram                           #    Boxplot                      Normal Probability Plot
  4.1+*                                              5       *           4.1+                                              ***
     .                                                                      |
     .                                                                      |
  3.5+                                                                   3.5+
     .                                                                      |
     .**                                            10       *              |                                         ****
  2.9+                                                                   2.9+
     .                                                                      |
     .                                                                      |                                              +
  2.3+                                                                   2.3+                                          ++++
     .*****                                         45       *              |                              **********++
     .                                                                      |                                  ++++
  1.7+                                                                   1.7+                              ++++
     .                                                                      |                          ++++
     .                                                                      |                      ++++
  1.1+******************************************   395    +--+--+        1.1+************************************
      ----+----+----+----+----+----+----+----                               +----+----+----+----+----+----+----+----+----+
      * may represent up to 9 counts                                           -2        -1         0        +1        +2
```

Univariate Procedure

Variable=X5 P-LOSS in sediment (lbs/a)

Moments

N	455	Sum Wgts	455
Mean	29.40185	Sum	13377.84
Std Dev	89.36982	Variance	7986.965
Skewness	5.621198	Kurtosis	37.6538
USS	4019415	CSS	3626082
CV	303.9599	Std Mean	4.189722
T:Mean=0	7.017613	Prob>|T|	0.0001
Num ¬= 0	358	Num > 0	358
M(Sign)	179	Prob>|M|	0.0001
Sgn Rank	32130.5	Prob>|S|	0.0001
W:Normal	0.367545	Prob<W	0.0001

Quantiles(Def=5)

100% Max	909.72	99%	533.34
75% Q3	15.7	95%	140.45
50% Med	3.07	90%	59.82
25% Q1	0.37	10%	0
0% Min	0	5%	0
		1%	0
Range	909.72		
Q3-Q1	15.33		
Mode	0		

Extremes

Lowest	Obs	Highest	Obs
0(	450)	533.34(	439)
0(	449)	535.94(	258)
0(	448)	588.9(	315)
0(	445)	666.19(	140)
0(	441)	909.72(	99)

```
                 Histogram                          #   Boxplot
 925+*                                              1      *
    .
    .
    .
    .
    .*                                              1      *
    .
    .*                                              1      *
    .*                                              2      *
 475+*                                              3      *
    .
    .*                                              1      *
    .*                                              3      *
    .*                                              2      *
    .*                                              1      *
    .*                                              5      *
    .**                                            10      *
    .****                                          28      0
  25+************* ******************************  397  +--0--+
     ----+----+--- +----+----+----+----+----+----+
     * may represe t up to 9 counts
```

```
                   Normal Probability Plot
 925+                                                   *
    |
    |
    |
    |                                                   *
    |
    |                                                   *
    |                                                 **
 475+                                               **
    |
    |                                               *
    |                                              *
    |                                             *     +
    |                                             *+++++
    |                                        ++++++
    |                                  ++++++ ***
    |                            +++++    *****
  25+*****************************************
     +----+----+----+----+----+----+----+----+----+----+
         -2        -1         0        +1        +2
```

```
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                                     Univariate Procedure

Variable=X6           P-LOSS in water (ppm)

                Moments                           Quantiles(Def=5)                         Extremes

N               455  Sum Wgts        455     100% Max        1       99%        1     Lowest    Obs    Highest    Obs
Mean       0.021978  Sum              10      75% Q3         0       95%        0        0(     455)         1(     82)
Std Dev    0.146773  Variance   0.021542      50% Med        0       90%        0        0(     454)         1(    162)
Skewness   6.542514  Kurtosis   40.98463      25% Q1         0       10%        0        0(     453)         1(    363)
USS              10  CSS         9.78022       0% Min        0        5%        0        0(     452)         1(    365)
CV         667.8175  Std Mean   0.006881                              1%        0        0(     451)         1(    383)
T:Mean=0   3.194096  Prob>|T|     0.0015     Range           1
Num ¬= 0         10  Num > 0          10     Q3-Q1           0
M(Sign)           5  Prob>|M|     0.0020     Mode            0
Sgn Rank       27.5  Prob>|S|     0.0020
W:Normal   0.137655  Prob<W       0.0001

                 Histogram                          #  Boxplot                       Normal Probability Plot
 1.025+*                                           10     *       1.025+                                              ******
      .                                                                |
 0.925+                                                           0.925+
      .                                                                |
 0.825+                                                           0.825+
      .                                                                |
 0.725+                                                           0.725+
      .                                                                |
 0.625+                                                           0.625+
      .                                                                |
 0.525+                                                           0.525+
      .                                                                |
 0.425+                                                           0.425+
      .                                                                |                                              +++
 0.325+                                                           0.325+                                           ++++
      .                                                                |                                        +++
 0.225+                                                           0.225+                                     +++
      .                                                                |                                 ++++
 0.125+                                                           0.125+                              +++
      .                                                                |                          ++++
 0.025+*********************************************  445   +--+--+   0.025+*********************************************
       ----+----+----+----+----+----+----+----+----                    +----+----+----+----+----+----+----+----+----+----+
       * may represent up to 10 counts                                      -2        -1         0        +1        +2
```

Univariate Procedure

Variable=X21 SEDIMENT YIELD (tons/a)

Moments

N	455	Sum Wgts	455
Mean	19.28842	Sum	8776.229
Std Dev	45.06285	Variance	2030.66
Skewness	2.948223	Kurtosis	8.340602
USS	1091199	CSS	921919.8
CV	233.6265	Std Mean	2.112579
T:Mean=0	9.13027	Prob>|T|	0.0001
Num ¬= 0	398	Num > 0	398
M(Sign)	199	Prob>|M|	0.0001
Sgn Rank	39700.5	Prob>|S|	0.0001
W:Normal	0.48722	Prob<W	0.0001

Quantiles(Def=5)

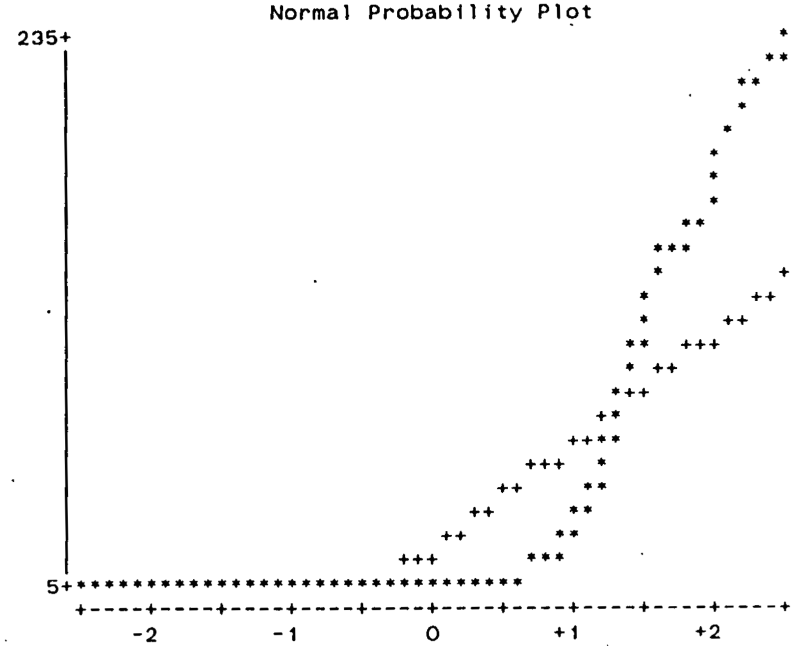
100% Max	234.5255	99%	217.0625
75% Q3	10.41875	95%	141.909
50% Med	0.85725	90%	72.63625
25% Q1	0.03925	10%	0
0% Min	0	5%	0
		1%	0
Range	234.5255		
Q3-Q1	10.3795		
Mode	0		

Extremes

Lowest	Obs	Highest	Obs
0(	439)	217.0625(	298)
0(	435)	227.5523(	443)
0(	425)	229.8768(	270)
0(	424)	231.7053(	266)
0(	418)	234.5255(	215)

```
      Histogram                                            #   Boxplot
235+*                                                      2      *
   .*                                                      2      *
   .*                                                      2      *
   .*                                                      1      *
   .*                                                      2      *
   .*                                                      1      *
   .*                                                      1      *
   .*                                                      1      *
   .*                                                      5      *
   .*                                                      6      *
   .*                                                      4      *
   .*                                                      2      *
   .*                                                      2      *
   .*                                                      4      *
   .*                                                      5      *
   .*                                                      2      *
   .*                                                      4      *
   .*                                                      3      *
   .*                                                      6      *
   .*                                                      8      0
   .*                                                      7      0
   .**                                                    11      0
   .*****                                                 36   +--+--+
  5+******************************************           338   *-----*
    ----+----+----+----+----+----+----+----+---
    * may represent up to 8 counts
```

Normal Probability Plot



Univariate Procedure

Variable=X41   N-Loss in water (ppm/a)

Moments

N	455	Sum Wgts	455
Mean	0.029396	Sum	13.375
Std Dev	0.012633	Variance	0.00016
Skewness	3.366746	Kurtosis	12.38072
USS	0.465625	CSS	0.072459
CV	42.97691	Std Mean	0.000592
T:Mean=0	49.63299	Prob>|T|	0.0001
Num ¬= 0	455	Num > 0	455
M(Sign)	227.5	Prob>|M|	0.0001
Sgn Rank	51870	Prob>|S|	0.0001
W:Normal	0.396591	Prob<W	0.0001

Quantiles(Def=5)

100% Max	0.1	99%	0.1
75% Q3	0.025	95%	0.05
50% Med	0.025	90%	0.05
25% Q1	0.025	10%	0.025
0% Min	0.025	5%	0.025
		1%	0.025
Range	0.075		
Q3-Q1	0		
Mode	0.025		

Extremes

Lowest	Obs	Highest	Obs
0.025(	455)	0.1(	9)
0.025(	454)	0.1(	26)
0.025(	453)	0.1(	81)
0.025(	452)	0.1(	82)
0.025(	451)	0.1(	383)

```
              Histogram                                #    Boxplot
0.1025+*                                               5       *
      .
      .
0.0875+
      .
      .**                                             10       *
0.0725+
      .
      .
0.0575+
      .*****                                          45       *
      .
0.0425+
      .
      .
0.0275+********************************************  395    +--+--+
       ----+----+----+----+----+----+----+----+----
       * may represent up to 9 counts
```

```
                   Normal Probability Plot
0.1025+                                                       ***
      |
0.0875+
      |                                                  ****
0.0725+
      |                                                        +
0.0575+                                                    ++++
      |                                     **********++
      |                                       ++++
0.0425+                                   ++++
      |                               ++++
      |                           ++++
0.0275+***********************************
       +----+----+----+----+----+----+----+----+----+----+
           -2        -1         0        +1        +2
```

```
                                        Lake Icaria Watershed                    14:11 Thursday, April 8, 1993   9

                                         Univariate Procedure

Variable=X61         P-Loss in water (ppm/a)

                Moments                              Quantiles(Def=5)                              Extremes

 N               455  Sum Wgts        455     100% Max     0.025       99%     0.025       Lowest    Obs     Highest    Obs
 Mean       0.000549  Sum            0.25      75% Q3          0       95%         0           0(    455)    0.025(     82)
 Std Dev    0.003669  Variance   0.000013      50% Med         0       90%         0           0(    454)    0.025(    162)
 Skewness   6.542514  Kurtosis   40.98463      25% Q1          0       10%         0           0(    453)    0.025(    363)
 USS         0.00625  CSS        0.006113       0% Min         0        5%         0           0(    452)    0.025(    365)
 CV         667.8175  Std Mean   0.000172                               1%         0           0(    451)    0.025(    383)
 T:Mean=0   3.194096  Prob>|T|     0.0015     Range        0.025
 Num ^= 0         10  Num > 0          10     Q3-Q1            0
 M(Sign)           5  Prob>|M|     0.0020     Mode             0
 Sgn Rank       27.5  Prob>|S|     0.0020
 W:Normal   0.137655  Prob<W       0.0001

                  Histogram                          #   Boxplot                       Normal Probability Plot
 0.0255+*                                           10      *       0.0255+                                                 ******
       .                                                                  |
       .                                                                  |
       .                                                                  |
 0.0205+                                                            0.0205+
       .                                                                  |
       .                                                                  |
       .                                                                  |
 0.0155+                                                            0.0155+
       .                                                                  |
       .                                                                  |
       .                                                                  |
 0.0105+                                                            0.0105+                                                    ++
       .                                                                  |                                                 +++
       .                                                                  |                                              +++
       .                                                                  |                                           +++
 0.0055+                                                            0.0055+                                             ++
       .                                                                  |                                          +++
       .                                                                  |                                       +++
       .                                                                  |                                    +++
 0.0005+*********************************************      445   +--+--+    0.0005+*****************************************++*****
        ----+----+----+----+----+----+----+----+----+                            +----+----+----+----+----+----+----+----+----+
        * may represent up to 10 counts                                               -2        -1         0        +1        +2
```